THE PICTURE OF THE TAOIST GENII PRINTED ON THE COVER of this book is part of a painted temple scroll, recent but traditional, given to Mr Brian Harland in Szechuan province (1946). Concerning these four divinities, of respectable rank in the Taoist bureaucracy, the following particulars have been handed down. The title of the first of the four signifies 'Heavenly Prince', that of the other three 'Mysterious Commander'.

At the top, on the left, is Liu *Thien Chün*, Comptroller-General of Crops and Weather. Before his deification (so it was said) he was a rain-making magician and weather forecaster named Liu Chün, born in the Chin dynasty about +340. Among his attributes may be seen the sun and moon, and a measuring-rod or carpenter's square. The two great luminaries imply the making of the calendar, so important for a primarily agricultural society, the efforts, ever renewed, to reconcile celestial periodicities. The carpenter's square is no ordinary tool, but the gnomon for measuring the lengths of the sun's solstitial shadows. The Comptroller-General also carries a bell because in ancient and medieval times there was thought to be a close connection between calendrical calculations and the arithmetical acoustics of bells and pitch-pipes.

At the top, on the right, is *Wen Yüan Shuai*, Intendant of the Spiritual Officials of the Sacred Mountain, Thai Shan. He was taken to be an incarnation of one of the Hour-Presidents (*Chia Shen*), i.e. tutelary deities of the twelve cyclical characters (see Vol. 4, pt. 2, p. 440). During his earthly pilgrimage his name was Huan Tzu-Yü and he was a scholar and astronomer in the Later Han (*b.* + 142). He is seen holding an armillary ring.

Below, on the left, is Kou *Yüan Shuai*, Assistant Secretary of State in the Ministry of Thunder. He is therefore a late emanation of a very ancient god, Lei Kung. Before he became deified he was Hsin Hsing, a poor woodcutter, but no doubt an incarnation of the spirit of the constellation Kou-Chhen (the Angular Arranger), part of the group of stars which we know as Ursa Minor. He is equipped with hammer and chisel.

Below, on the right, is Pi *Yüan Shuai*, Commander of the Lightning, with his flashing sword, a deity with distinct alchemical and cosmological interests. According to tradition, in his early life he was a countryman whose name was Thien Hua. Together with the colleague on his right, he controlled the Spirits of the Five Directions.

Such is the legendary folklore of common men canonised by popular acclamation. An interesting scroll, of no great artistic merit, destined to decorate a temple wall, to be looked upon by humble people, it symbolises something which this book has to say. Chinese art and literature have been so profuse, Chinese mythological imagery so fertile, that the West has often missed other aspects, perhaps more important, of Chinese civilisation. Here the graduated scale of Liu Chün, at first sight unexpected in this setting, reminds us of the ever-present theme of quantitative measurement in Chinese culture; there were rain-gauges already in the Sung (+12th century) and sliding calipers in the Han (+1st). The armillary ring of Huan Tzu-Yü bears witness that Naburiannu and Hipparchus, al-Naqqash and Tycho, had worthy counterparts in China. The tools of Hsin Hsing symbolise that great empirical tradition which informed the work of Chinese artisans and technicians all through the ages.

SCIENCE AND CIVILISATION IN CHINA

Joseph Needham
(1990–1995)

'Certain it is that no people or group of peoples has had a monopoly in contributing to the development of Science. Their achievements should be mutually recognised and freely celebrated with the joined hands of universal brotherhood.'

Science and Civilisation in China VOLUME I, PREFACE

*

Joseph Needham directly supervised the publication of seventeen books in the *Science and Civilisation in China* series, from the first volume, which appeared in 1954, through to Volume VI.3, which was in press at the time of his death in March 1995.

The planning and preparation of further volumes will continue. Responsibility for the commissioning and approval of work for publication in the series is now taken by the Publications Board of the Needham Research Institute in Cambridge, under the chairmanship of Dr Christopher Cullen, who acts as general editor of the series.

SCIENCE AND CIVILISATION IN CHINA

All the handicrafts possess a scientific content which has grown up along with them and is embodied in their practice. The manufactured article is the joint product of the science and the practice which are combined in the handicraft.

PLATO (*c.* −427 to −347, *Politicus*, 258)

.....

A question: If man's nature is evil, then how do ritual principles and moral duty develop?

The answer: They result from the acquired nature of intelligent men, and are not an inborn characteristic of human nature. The process is illustrated by pottery making, where a ceramic vessel is the result of the potter's efforts in mixing clay and shaping it with his hands. Such vessels are not the product of anything inherent in the potter's inborn nature, but result from his acquired nature.

問者曰：人之性惡，則禮儀安從生？
應之曰：凡禮儀者，是生於聖人之僞，非故生於人之性也，故陶人埏
埴而爲器，然則器生於陶人之僞，非故生於人之性也

HSÜN TZU (*c.* −240), writing about human nature.

中國科學技術史

李約瑟著

冀朝鼎

JOSEPH NEEDHAM

SCIENCE AND CIVILISATION IN CHINA

VOLUME 5

CHEMISTRY AND CHEMICAL TECHNOLOGY

PART XII: CERAMIC TECHNOLOGY

EDITOR

ROSE KERR

BY

ROSE KERR AND NIGEL WOOD

WITH CONTRIBUTIONS FROM

TS'AI MEI-FEN AND ZHANG FUKANG

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To Dr **LEE** SENG TEE 李成智 of Singapore

A worthy successor to his father

THE LATE TAN SRI DR **LEE** KONG CHIAN 李光前

as encourager and sustainer of the *Science and Civilisation in China* project
this volume is dedicated with gratitude.

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ABBREVIATIONS

WESTERN JOURNALS

A	*Archaeometry*
AC	*Acta Crystalographa*
AA	*Arts Asiatiques*
AAA	*Archives of Asian Art*
ACASA	*Archives of the Chinese Art Society of America*
ACP	*Annales de Chemie et Physique*
ACRO	*Asian Ceramics Research Organization*
ACSB	*American Ceramic Society Bulletin*
AJ	*The Antiquaries Journal*
AJA	*American Journal of Archaeology*
AM	*Asia Major*
AmAn	*American Antiquity*
AO	*Ars Orientalis*
AoA	*Arts of Asia*
Ap	*Apollo*
ArC	*Ars Ceramica*
ARLC	*Annual Reports of the Librarian of Congress*
ArM	*Archeomaterials*
ArP	*Archaeo-Physika*, Bonn
AS	*Applied Spectroscopy*
BM	*Burlington Magazine*
BMFEA	*Bulletin of the Museum of Far Eastern Antiquities*, Stockholm
BSOAS	*Bulletin of the School of Oriental and African Studies*
C	*Chemosphere*
CB	*Ceramic Bulletin*
CCM	*Clays and Clay Minerals*
CM	*Ceramics Monthly*
CR	*China Reconstructs*
CT	*Ceramics Technical*
EMD	*Engineering Materials and Design*
FECB	*Far Eastern Ceramic Bulletin*
FEQ	*The Far Eastern Quarterly*
HJAS	*Harvard Journal of Asian Studies*
HM	*Historical Metallurgy*
I	*Iran*
ILN	*Illustrated London News*
ISIS	*Isis*

JACS	*Journal of the American Ceramic Society*
JAOS	*Journal of American Oriental Studies*
JAS	*Journal of Archaeological Science*
JCAJ	*Journal of the Ceramic Association of Japan*
JEA	*Journal of Egyptian Archaeology*
JGS	*Journal of Glass Studies*
JGT	*Journal of Glass Technology*
JMBRAS	*Journal of the Malayan Branch of the Royal Asiatic Society*
JPC	*Journal of Physical Chemistry*
JWCI	*Journal of the Warburg and Courtauld Institutes*
JWH	*Journal of World History*
MC	*Medieval Ceramics*
MI(U)	*Museum International (UNESCO)*, Paris
MM	*Mineralogical Magazine*
MRDTB	*Memoirs of the Research Department of the Tokyo Bunko*
MS	*Ming Studies*
MSB	*Mineralogical Society Bulletin*
N	*Nature*
NS	*New Scientist*
O	*Orientations*
OA	*Oriental Art*
OCSHKB	*The Oriental Ceramic Society of Hong Kong Bulletin*
OxJA	*The Oxford Journal of Archaeology*
P	*Polyhedron*
PQ	*Pottery Quarterly*
PSAS	*Proceedings of the Seminar For Arabian Studies*
QJGS	*Quarterly Journal of the Geological Society*
QSR	*Quaternary Science Reviews*
S	*Science*
SA	*Scientific American*
SC	*Studies in Conservation*
SIK	*Stecklo I Keramika*, Moscow
ST	*Silikattechnik*, Berlin
T	*Techne*
TACS	*Transactions of the American Ceramic Society*
TAM	*The American Mineralogist*
TC	*Technology and Culture*
TECC	*Transactions of the English Ceramic Circle*
TOCS	*Transactions of the Oriental Ceramic Society*
TP	*T'oung Pao*
VS	*Vietnamese Studies*

CHINESE JOURNALS

CKSYHHP	*Chiangsi Kuei-Suan-Yen Hsüeh Hui Pao* 江西硅酸鹽學會報
CKTTYC	*Chung Kuo Thao Tzhu Yen Chiu* 中國陶瓷研究
CTCFC	*Ching-te-chen Fang Chih* 景德鎮方志
CTCTT	*Ching-te-chen Thao Tzhu* 景德鎮陶瓷
CTCTTHYHP	*Ching-te-chen Thao Tzhu Hsüeh Yüan Hsüeh Pao* 景德鎮陶瓷學院學報
CWW	*Chiangsi Wen Wu* 江西文物
FWP	*Fukien Wen Po* 福建文博
HCSYC	*Hai Chiao Shih Yen Chiu* 海交史研究
HHKK	*Hua Hsia Khao Ku* 華夏考古
HHWW	*Hung-Hsi Wen Wu* 鴻禧文物
HWSYC	*Hai Wai Shih Yen Chiu* 海外史研究
ISH	*I Shu Hsüeh* 藝術學
KK	*Khao Ku* 考古
KKCK	*Ku-Kung Chi Khan* 故宮季刊
KKHP	*Khao Ku Hsüeh Pao* 考古學報
KKHSCK	*Ku-Kung Hsüeh Shu Chi Khan* 故宮學術季刊
KKPWYYK	*Ku-Kung Po Wu Yüan Yüan Khan* 故宮博物院院刊
KKWWYK	*Ku-Kung Wen Wu Yüeh Khan* 故宮文物月刊
KSYHP	*Kuei-Suan-Yen Hsüeh Pao* 硅酸鹽學報
LSWW	*Li Shih Wen Wu* 歷史文物
MSSYCCK	*Mei Shu Shih Yen Chiu Chi Khan* 美術史研究集刊 (Taida Journal of Art History, Taipei)
NFWW	*Nan-Fang Wen Wu* 南方文物
SHPWKCK	*Shanghai Po Wu Kuan Chi Khan* 上海博物館集刊
TTYC	*Thao Tzhu Yen Chiu* 陶瓷研究
WS	*Wen Shih* 文史
WW	*Wen Wu* 文物
WWCC	*Wen Wu Chhun Chhiu* 文物春秋
WWPHYKKKH	*Wen Wu Pao Hu Yü Khao Ku Kho Hsüeh* 文物保護與考古科學
WWTKTL	*Wen Wu Tshan Khao Tzu Liao* 文物參考資料

CHINESE AND JAPANESE BOOK COLLECTIONS, TSHUNG-SHU, SERIES AND PUBLISHERS

CHSC	*Chung Hua Shu Chü* 中華書局
CKFCTS	*Chung Kuo Fang Chih Tshung Shu* 中國方志叢書
CKHCSCPS	*Chiangsu Kho Hsüeh Chi Shu Chhu Pan She* 江蘇科學技術出版社
CKSCHP	*Chung Kuo Sheng Chih Hui Pien* 中國省志匯編
CKSHTS	*Chung Kuo Shih Hsüeh Tshung Shu* 中國史學叢書
CKWHCPTS	*Chung Kuo Wen Hsüeh Chen Pen Tshung Shu* 中國文學珍本叢書

CPTCTS	*Chih Pu Tsu Chai Tshung Shu* 知不足齋叢書
CWCPS	*Chen Wen Chhu Pan She* 珍文出版社
CYSFHC	*Chieh Yüeh Shan Fang Hui Chhao* 借月山房匯鈔
CYWYKSKCS	*Ching Yin Wen Yüan Ko Ssu Khu Chhüan Shu* 景印文淵閣四庫全書
FJMCPS	*Fukien Jen Min Chhu Pan She* 福建人民出版社
HFL	*Han Fen Lou* 涵芬樓
HHCPS	*Hsüeh Hai Chhu Pan She* 學海出版社
HHSC	*Hsin Hsing Shu Chü* 新興書局
HMTTS	*Hsün Min Thang Tshung Shu* 遜敏堂叢書
HWFCY	*Hsin Wen Feng Chung Yin* 新文豐重印
HWFSC	*Hsin Wen Feng Shu Chü* 新文豐書局
HYHTS	*Hsi Yin Hsüan Tshung Shu* 惜陰軒叢書
HYLTC	*Hua Yü Lou Tshung Chhao* 花雨樓叢鈔
HYTS	*Hsiao Yüan Tshung Shu* 嘯園叢書
KWSC	*Kuang Wen Shu Chü* 廣文書局
MCPCTS	*Ming Chhing Pi Chi Tshung Shu* 明清筆記叢書
MSTS	*Mei Shu Tshung Shu* 美術叢書
PCHP	*Pi Chi Hsü Pien* 筆記續編
PCHSTKCP	*Pi Chi Hsiao Shuo Ta Kuan Cheng Pien* 筆記小說大觀正編
PYTPC	*Pao Yen Thang Pi Chi* 寶顏堂秘笈
SCSC	*Shih Chieh Shu Chü* 世界書局
SF	*Shuo Fu* 說郛
SKCSCPPC	*Ssu Khu Chhüan Shu Chen Pen Pa Chi* 四庫全書珍本八集
SKCSTMTY	*Ssu Khu Chhüan Shu Tsung Mu Thi Yao* 四庫全書總目提要
SPPY	*Ssu Pu Pei Yao* 四部備要
SPTK	*Ssu Pu Tshung Khan* 四部叢刊
SSCCS	*Shih San Ching Chu Shu* 十三經注疏
SWYSK	*Shang Wu Yin Shu Kuan* 商務印書館
SWSC	*Shang Wu Shu Chü* 商務書局
TLIS	*Tsui Li I Shu* 檇李遺書
TLKKTS	*Tshui Lang Kan Kuan Tshung Shu* 翠嘯玕館叢書
TSCC	*Tshung Shu Chi Chheng* 叢書集成
TT	*Tao Tsang* 道藏
TTPL	*Thao Tzhu Phu Lu* 陶瓷譜錄
TTTS	*Thang Tai Tshung Shu* 唐代叢書
TWSC	*Ting Wen Shu Chü* 鼎文書局
WCIC	*Wang Chien I Chi* 王諫議集
WHST	*Wen Hsing Shu Tien* 文星書店
WHTP	*Wen Hsien Tshung Pien* 文獻叢編
WLCKTP	*Wu Lin Chang Ku Tshung Pien* 武林掌故叢編
WMSC	*Wen Ming Shu Chü* 文明書局
YYTTS	*Yüeh Ya Thang Tshung Shu* 粵雅堂叢書

SERIES EDITOR'S PREFACE

As Rose Kerr and Nigel Wood point out in their preface, in the first volume of *SCC* published in 1954 Joseph Needham outlined plans for subsequent volumes in what was then envisaged as a series of seven moderate-sized books. Volume 5, then labelled 'Chemistry and Industrial Chemistry', was to contain Section 33 on Alchemy and Chemistry, 34 on Chemical Technology, 35 on Ceramic Technology, 36 on Mining and Metallurgy, and 37 on the Salt industry. The proposed content of the section on Ceramic Technology was outlined in just seven words.

Readers of this series will be familiar with the immense growth in the bulk of Needham's volumes as the years from 1954 to the present unrolled. All volumes from 4 onwards split into several physically separate books – what Needham called 'earthly volumes' as opposed to the original 'heavenly volumes'. Some sections eventually split into several physically distinct books of considerable bulk: thus section 36 has seen the publication of one book devoted entirely to Mining, while two further metallurgical books are on their way through the system. In some cases, such as the Salt Industry, a section became a single book, now close to completion. Around 1980, however, the archives of the project reveal little more detail of what was to become of ceramics, apart from the addition of the words 'Digression on *cloisonné*'. There was a name of a collaborator who it was hoped would eventually produce the material required, but that is all that had been achieved.

When I began my own association with the *SCC* project in 1992, it was clear that this was one of the books in the series for which a manuscript was unlikely to be delivered in the foreseeable future. Joseph Needham agreed that a new start needed to be made, and after consultation it was agreed in 1994 to ask Rose Kerr to propose a new plan for a book on ceramic technology in its fullest historical and social context. In view of her internationally acknowledged expertise and wide network of scholarly contacts, her agreement came as a great encouragement to everybody concerned with the project. Eventually the other pieces of the jigsaw came together in the form of a generous grant from the Chiang Ching-Kuo Foundation for International Scholarly Exchange and the agreement of the Trustees of the Victoria and Albert Museum to grant Rose a sabbatical year to begin work on the volume. Rose was soon joined by a distinguished group of co-workers, of whom the chief was Nigel Wood, and work began.

All such tasks take longer than would seem likely at first, but at last the magnificent result of all this toil and expense is before us. Its subject demanded that it should be the first volume in the series to be illustrated in colour throughout, and we are most grateful to the Lu Gwei-djen Memorial Charitable Trust for a grant to subsidise the extra costs involved. Joseph Needham sadly died long before drafts of

this book began to appear; but he was delighted when it became clear that there would indeed be a book on ceramics in the great series he founded, and I know that this excellent book, surely destined to become a monument in its field, would have given him immense pride and pleasure.

Christopher Cullen
General Editor
Director, Needham Research Institute
Cambridge

PREFACE

When Joseph Needham published the first volume of his magisterial series *Science and Civilisation In China* in 1954, he had a clear conception of future progress. At the front of the book was laid out a conspectus of contents of the six subsequent volumes he then envisaged. Starting with exhaustive discussion of the history of scientific thought in China, it passed to consideration of the 'pure sciences': mathematics, astronomy, physics and chemistry. Linked to those subjects were the applied sciences: geography, geology, mineralogy, engineering. Needham had already outlined in some detail future treatment of nautical and military technology, but noted that other sciences, pseudo-sciences and technologies were still under consideration. Nevertheless, he included indicative outlines for certain subjects such as alchemy, agriculture, mining and metallurgy. Other topics were sketched in a more rudimentary manner. The briefest citation of all was that under the future section 35 of volume 5 devoted to *Ceramic Technology*: it merely intimated that the contents would discuss 'History of pottery, porcelain, felspathic glazes, etc.'

The fact that ceramics came at the back of the queue of ideas jostling for a place in Joseph Needham's schema is both intimidating and encouraging. Intimidating, because it was apparent both then and since that ceramics were not of primary interest to Needham personally, though he recognised the significance of their technological history and global influence. Encouraging, because his insouciance coupled with his academic generosity of spirit left the field wide open to scholars contributing to the series. We are honoured and pleased to have been given the opportunity to deliver a volume, for Joseph Needham's reputation and literary legacy ensure that it should gain broad currency in a vast literature devoted to Chinese ceramics.

All authors must surely consider their own area of study to be immense; as research is pursued, the chosen subject expands to seemingly infinite proportions. The present authors are no exception, for they have striven to reconcile several facets of ceramic study within this one volume. Foremost is examination of the technology of pottery- and porcelain-making, with all its broad ramifications and long gestation. Considering first clays, we have been drawn into discussion of the underlying geologies of China. Pots are made of rock and clay, and glazes are fired surface coatings of which body-clay is often a component. Clays are composed of decomposed rock, and therefore an understanding of regional geological characteristics is essential in determining the choice and the processing of raw materials, and their concomitant results. The behaviour of clays under shearing-pressure, the mixing of glazes and the conduct of both when subjected to firing, involves the application of principles of both physics and chemistry. In the construction and firing of kilns, we find that basic knowledge of engineering, physics and chemistry is helpful. The evolution and progression of kiln design in different regions of China, modified to suit

local raw and fuel materials, demonstrated achievements in all those fields. The character of various fuels and the principles of combustion must be explored, as must the nature of oxidation, reduction and hydrogen reduction within the burning kiln. The setting of wares within a kiln utilised similar skills to those engaged in their forming. Long apprenticeship ensured optimum results with minimum effort. Indeed, the forming of ceramics is perhaps the most difficult of all areas accurately to document, for though textual evidence is abundant, current practice may show several routes leading to similar results. Paradoxically, the forming of sophisticated products is often easier to chart than the fashioning of simple ones. Thus construction of porcelain vessels at Ching-te-chen 景德鎮 (the 'porcelain city' of China) has been described in minute detail from the +13th century onwards, and modern manufacture can confirm processing methods. By contrast, simple pottery vessels that were coiled, hand-built or thrown and subsequently refined with paddle-and-anvil, had no recorded history. Moreover, modern village potters demonstrate that widely differing techniques and sequences of potting can give rise to identical end-products. The literature and practice associated with glazes is substantial. Glaze and glass technology are closely linked, and lead us back once more to geology. Many glazes are tinged by the addition of colouring minerals, while Chinese potters also coated the surface of ceramics with coloured slips and enamels. Comprehension of those substances also involves the investigation of the mineralogy of ceramic raw materials.

Of course, the history of pre-modern ceramic technology in China involved the development of skills based on empirical research over long periods of time. It took some 3,000 years for the potters of Neolithic China to progress from simple bonfire-firing to firing in updraft kilns, where the combustion area for fuel was separated from the ceramics being fired. Potters depended on causal thinking, adapting technology to suit requirements. Once they had achieved a commercially successful product such as high-fired, green-glazed stoneware they were unwilling to make major modifications until the market demanded them, or environmental factors such as deforestation necessitated them, or information from elsewhere suggested achievable improvement. The major promoters of technological transfer and change were the emperors of China. From at least as early as the Thang dynasty (+618–906) the imperial court requisitioned vessels for ritual and everyday use. This initially led to the selection of the finest wares from private kilns all over China, but it also encouraged the creation of novel ceramic effects, most notably in glazing. Once a depot devoted to imperial manufacture was set up at Ching-te-chen in the +13th century, technicians at the factory were subjected to repeated demands for innovatory products, many of them stimulated by receipt of tributary artefacts from beyond the borders of China. New shapes were potted, often with immense difficulty and high failure rate. Glaze recipes were improved, while trials were conducted with a palette of overglaze enamel colours. In the first half of the +18th century, enamelling was the focus of intense experimentation within the workshops of the palace at Peking, and the imperial kiln at Ching-te-chen. The massive support

that central government procurement of ceramics guaranteed gave technological superiority to the whole Chinese ceramics industry. For well over 1,500 years China supplied ceramics to the world, and for most of that time she controlled a monopoly product in the form of porcelain. It was not until the +19th century that developments in the pottery factories of Europe, most of them concerned with improvement to manufacturing methods and marketing, caused China's eclipse in the world ceramics market.

We have mentioned China's tributary contacts with the outside world and her lucrative merchandising of ceramics. We also discuss patterns of trade in the book, considering first the ancient associations established within East and South-east Asia, then subsequent contacts across the Arab world. Although Chinese ceramics played such a dominant role in the West, their arrival was late in the historical cycle. A trickle of items received during the Middle Ages increased to a veritable flood of porcelain shipped westwards during the +17th and +18th centuries. Thus from the middle of the first millennium until the end of the +18th century, Chinese ceramics played a major part in the lives of people across the globe, and in their desire to emulate products potters evolved strategies of forming, glazing and firing that local raw materials permitted. It truly can be said that not only Chinese pots, but also Chinese ceramic technology, made major contributions to the world economy. Then, after years of decline in the +19th and first half of +20th centuries, China once more rejoined the international ceramic community. This time she contributed as a junior partner, in the areas of art pottery, mass-produced domestic china and sanitary ware. Perhaps the most promising current field is that of high-technology ceramics, for their global potential is immense. We devote a section to China's role in the development of +20th- to +21st-century advanced ceramics at the end of this volume.

What underpinned China's success in ceramic technology? What inspired her early brilliance, originality and creativity? We attempt to explain the phenomenon through three different avenues. First is a consideration of what history tells us, from textual sources in the canons of traditional literature. Second is an appraisal of different areas of the ceramic industry in terms of official control, production methods, organisation and markets. This approach leads to careful thought about the changing status of ceramics, for the value and regard afforded a material often affected the level of resources invested in technological breakthrough and improvement. An impressive example was the pottery business at Ching-te-chen, whose copious literary and artefactual evidence has justified extended description and discussion. Another sector was that concerned with building materials. Not only were these of major importance to local and national standards of life, but also they were among the first ceramic materials to be subject to government control. Archaeological excavation of ancient monuments and the textual information that official supervision ensured, allows us to glimpse great technological feats of manufacture.

The third method of study is that concerned with experimental production and scientific analysis. In China, trials based on empirical observation led to important

new formulations, such as the creation of artificial pigments in the Warring States period, or the simulation of fine Sung and Ming dynasty wares in the +18th century. Meanwhile, in +18th-century Europe, a major quest was underway to manufacture porcelain. Careful description of porcelain raw materials and production processes in the letters of missionaries helped the kiln masters in their search. Eventually, it was lengthy experimental trial that succeeded in formulating several ceramic substances with the qualities of white, vitreous porcelain. In the +19th century, Western scientists and ceramicists continued their interest in Chinese wares. Researchers travelled to Ching-te-chen, where they procured samples of body and glaze materials, and decorative pigments, returning with them for analysis in European laboratories. This scientific method of examining past ceramic achievements has intensified into structured programmes of research since +1949.

In the +19th and early +20th centuries, materials were usually analysed by the 'wet method', that is by progressive dissolution in various solvents. Through the use of this technique, one element at a time was removed from the material studied, and its concentration measured – a laborious but generally accurate process. Nowadays, materials may be analysed directly by an attachment to a scanning electron microscope ('microprobe analysis'), or by X-ray fluorescence spectroscopy. Both techniques work by bombarding the solid materials with electrons followed by an interpretation of the resulting X-ray spectra. A very recent development of this principle is PIXE (Proton Induced X-ray Emission Spectroscopy). This uses a nuclear accelerator to provide a proton, rather than an electron, beam, in order to generate the X-ray spectra. Another popular modern analytical method dissolves the material to be studied in acid, and then sprays the solution into an incandescent flame. In this case the coloured spectra that result are compared with known spectra of various elemental standards. Two techniques in particular that use this 'flame photometry' principle are Atomic Absorption Spectroscopy (AAS), and its more elaborate variant, ICPS (Inductively Coupled Plasma Spectroscopy). All six techniques give essentially the same results, with broadly similar levels of accuracy, but all provide proportional lists of *elements* rather than percentage lists of *oxides*. Further calculations are necessary, based on the ways that these elements are known to combine with oxygen, in order to establish oxide-lists such as those employed in this volume.

In the +1950s, when thorough-going studies in ceramic technology started in China, most major questions concerning materials and processing remained unanswered. Since that time, investigation at several major institutions under the aegis of the Chinese Academy of Sciences 中國科學院 has resulted in a plethora of published research that has greatly aided our comprehension of the subject. Research has been stimulated in the United Kingdom, America, Japan, Korea, France, Germany, Spain and Sweden, so that now the study of Chinese pottery and porcelain is an international undertaking. Indeed, more work has been carried out in relation to Chinese ceramics than to any other world tradition. When the authors were researching the design of English porcelain kilns in the +18th century, for example, they discovered more copious information was available for Chinese kilns

of the +8th century! Much remains to be done, however, and at any time new discoveries may be published. In some ways, there will never be a 'best moment' to issue such a book as this, as supplementary results will continue to emerge. Nevertheless, we are presently in receipt of quantities of data that make our study far more complete than would have been possible twenty or even ten years ago.

Perhaps the greatest boost to research in ceramic technology came when the First International Conference on Ancient Pottery and Porcelain (ICAPP) was held in Shanghai in November +1982. Some 67 papers from around the world, but chiefly from China itself, were presented during five days of a conference that changed the shape of ceramic research. Since +1982, six further meetings have been convened. The remit of investigation has broadened to include ceramics world-wide, and a perusal of works listed in Bibliographies B and C will give some idea of the range of topics covered to date. Some papers have as their purpose the successful, commercial reproduction of historical wares, just such an aim as that proclaimed in China in the +18th century. Others justify more abstract approaches to research, but all add small pieces to the complex mosaic of knowledge concerning Chinese ceramics.

Many people and institutions other than the two chief authors and contributing essayists have aided the successful completion of this work. Suning Sun-Bailey has worked with diligence to unearth old texts and to interpret a range of materials; her painstaking work has been of great value. Louise Kakoma has compiled lists of archaeological reports, while the authors' employers at the Victoria & Albert Museum, and the University of Westminster, have been generous with research time and encouragement. David McMullen, Peter Y. K. Lam, Rosemary Scott, Ian Freestone, Pamela Vandiver and the late David Kingery have read and commented on drafts, John Moffett has edited drafts and contributed much useful information, and Rose Kerr's colleagues in the Far Eastern Section of the Asian Department at the V&A have helped with queries concerning Chinese, Japanese and Korean texts while also supporting her preoccupation during long labour on the book. Nigel Wood acknowledges the great help provided by a British Academy/Leverhulme Trust Senior Research Fellowship in 2000–2001, and Research Fellowships and Research Associateships at the Research Laboratory for Archaeology and the History of Art, University of Oxford, for the period 1996–2002. Finally, we recognise that the volume could not have been attempted without financial support and recognition from the Chiang Ching-Kuo Foundation for International Scholarly Exchange.

September 2002 Rose Kerr and Nigel Wood

PART 1: SETTING THE SCENE

THE STATUS OF CERAMICS IN EARLY CHINA

The main subject of this book, as part of the series concerned with a scientific record of China, is the history of Chinese ceramic technology. That topic alone is extraordinarily rich, for China can evidence 11,000 continuous years of ceramic manufacture, utilising copious natural resources to achieve consummate technical successes. Broad issues pertaining to ceramic materials and processes will be introduced in this opening section of the volume. Prefacing those themes, however, will be a review of the manner in which effective political and economic organisation contributed to production at various levels in the community. For while ceramics were not always pre-eminent materials for ritual and status, they maintained an important role in Chinese society. They were utilised for medicinal and culinary purposes, extolled as objects of aesthetic refinement by scholars, mass-produced for export, and subjected to official control for burial, religious ritual and imperial household functions.

One route to knowledge is through consultation of historical texts. They provide only a partial view of the subject, and can be supplemented by commentary and research conducted by modern scholars, in both textual and archaeological fields. In Part 1 these types of research material are employed to sketch a background to the story of Chinese ceramics, starting with consideration of the status of pottery at the very dawn of history.

PALAEOLITHIC AND NEOLITHIC PERIODS

In the period *c.* −9,000 to −4,000, carbon-dated sites of Phei-li-kang 裴李崗 and Hsin-cheng 新鄭 in Honan province 河南省, Tzhu-shan 磁山 in Hopei province 河北省, Tseng-phi-yen 甑皮岩 in Kuangsi province 廣西省 and Hsien-jen-tung 仙人洞 in Chiangsi province 江西省, show evidence of pottery production.[1] Consideration of just one of these early ceramic-yielding sites offers some interesting pointers to later developments. The cave site called Hsien-jen-tung, or 'Spirit Cave', lies in the Wan-nien 萬年 district of north-eastern Chiangsi province. The cave was formed in a limestone cliff, and held three layers of deposition, the last of which contained the debris of human occupation. First investigated in +1962, the site has been the focus of several archaeological reports,[2] and has recently been the subject of extensive re-examination as part of a joint project between Chinese and American archaeologists. The Sino-American team affirmed that the time horizons for the whole site were −9,000 to −4,000, and that pottery recovered from the site

[1] Feng Hsien-Ming *et al.* (1982), pp. 1–5.
[2] Chang Kwang-Chih (1963, 1986), p. 100 and note 89.

used clay from a common source. The pots from all strata were formed by hand, using coiling, thinning and smoothing processes, with cording, stamping and piercing for decoration. A tentative sequence of pottery types has been established, the ceramics of some phases of the sequence containing both fine and coarse. Pottery of both types was placed in tombs situated in the communal burial ground to the north of the settlement; it is noticeable that few graves held fine types. For example, the earliest ceramic phase of *c.* –9,000, called by the archaeologists 'Hsien ware' 仙窯, was tempered with crushed white quartzite rock whose mineral-grains acted as a temper, ranging as they did from coarse to very coarse. Other ceramics later in the sequence were tempered using added, crushed pottery sherds, while a third type was shell-tempered.[3]

A point of interest is the presence of both fine and coarse wares in the same phases of occupation. Unfortunately the sherds from the very earliest phases of Hsien-jen-tung are too small to permit reconstruction of whole vessel-types, and the cave dwelling site does not encourage the re-creation of socio-cultural ritual. Nevertheless, there are two ways in which one may interpret the presence of fine and coarse ceramics. The first implies hierarchical division, with richer or more powerful members of clans owning finer pots and those of low status possessing coarse wares. The second interpretation implies the use of fine wares for ritual and ceremonial, and coarse wares for domestic purposes. Both interpretations must be conjectural, but in the light of evidence from the later Neolithic, the latter view seems more plausible.

Gina Barnes has rehearsed the different ways in which +20th-century archaeologists define the concept 'neolithic': in terms of material technology; by reference to social organisation; or by varying combinations of the two.[4] For China, it is often understood as the time at which peoples turned away from hunter-gathering, and established settled agricultural communities. This happened at different periods in different regions of China, starting around –9,000 to –7,000.[5] The range of ceramic types produced over this vast area and enormous time-span was very varied, and the evolving technologies of forming and firing were significant.

The definition just given of the Neolithic in China invites several problems, however. Archaeology has revealed the presence of sets of grouped sites (termed by the Chinese 'cultures') that post-date the last period of glaciation in China, variously dated to between –13,000 and –10,000.[6] These cultures belong to what K. C. Chang has called 'two ill-defined but clearly recognisable segments', i.e. those largely without ceramics, and those producing pottery. To complicate matters further, some of the earliest pottery-producing cultures were known to be agricultural, while others were not.[7]

[3] Hill (1995), pp. 35–45.
[4] Barnes (1993), pp. 16–18.
[5] Three maps from K. C. Chang's seminal book *The Archaeology of Ancient China* illustrate how several centres of activity developed and interconnected over four millennia. Chang Kwang-Chih (1963, 1986), p. 235.
[6] *Ibid.*, p. 71.
[7] *Ibid.*, p. 81.



Fig. 1 Pan-pho fine ware

Material from the middle Neolithic period in China is more abundant. A well-known site from this phase is Pan-pho 半坡 in Shensi province 陝西省, tentatively dated to −5,000 to −4,000.[8] The Pan-pho Neolithic village was built within a large moated clearing on the second terrace of the east bank of the Chhan river 滻河, some six kilometres east of present-day Sian 西安 city. The district is now largely treeless loess, but in its time grassland, marshes and dense virgin forest surrounded the Neolithic village and its fields. People of the Yang-shao culture 仰韶文化 at Pan-pho grew millet and Chinese cabbage, kept pigs, fished with barbed hooks and nets in the nearby river and lakes, hunted game (particularly banded deer), and gathered foods such as pine-nuts, chestnuts and snails. This took place in a warmer (perhaps +4°C) and wetter environment than exists in Shensi today. The substantial and ditch-protected village covered about 50,000 square metres, of which some 10,000 square metres have now been excavated. The site was discovered in +1953 and has since seen five systematic campaigns of excavation, and the building of a large roof to protect the dozens of hut foundations, storage pits and kilns discovered. Foundations for 46 houses (some semi-subterranean), two pigsties, more than 200 storage pits, six kilns and some 200 tombs have been found to date. Germane to the discussion are the large numbers of sherds that have been recovered, and the

[8] *Ibid.*, p. 111.



Fig. 2 Pan-pho coarse ware

presence of reconstructed whole ceramic vessels. From these artefacts it is immediately apparent that two categories of ceramics were made, those for everyday use and those for special feasting or ritual occasions.[9]

Areas of the village were reserved for pottery-making, the products including red or grey, thick-walled amphorae with pointed bases, *ting* 鼎 cooking tripods, wide-bellied storage jars with narrow necks, and a variety of basins, bowls, cups and

[9] In addition to fine vessels for use in life, distinctive sets of ceramics were already made for burial, that were smaller and not so fine. This creation of burial items (now termed in Chinese *ming-chhi* 明器) set a pattern that was to continue throughout Chinese history.

pouring vessels. These were made from both coarse and relatively fine pottery, some of which is recorded as being tempered with mica or sand, and some with shell.[10] A quite distinct group of artefacts was characterised by a fine, burnished red body, a coiled and paddled method of construction,[11] and decoration with red, white and black pigments (see also Parts 4 and 6 of this volume). Pottery of both types was placed in tombs situated in the communal burial ground to the north of the settlement; it is noticeable that few graves contained either tools or weapons.[12] A special ceremonial use of large, red-bodied, painted jars was to contain the remains of children or teenagers who had died young, the jars then being buried in the vicinity of houses.

The Hung-shan 紅山 and related Neolithic cultures in north-east China throw up yet more interesting contexts for the use of pottery. The site of Niu-ho-liang 牛河梁 in Liaoning province 遼寧省 has been carbon-14 dated to around –3,000.[13] In addition to cairn burials and houses, archaeologists also unearthed the remains of a large, subterranean building measuring about 25 by 9 metres. It was divided into several chambers, and its surface layers yielded fragments of big pottery figures of animals and humans. The human figures were life-sized, with ears of twice life-size. A famous piece is the model of a complete human head, with eyes inlaid with blue-green jade pieces for verisimilitude.[14]

Such figures, found at several Hung-shan sites, have been characterised as statues of deities, and Chinese archaeologists call the large building at Niu-ho-liang the 'Goddess Temple'.[15] In addition to pottery figures, fine black-painted red ceramic vessels were made, which has suggested a link between the Neolithic cultures of north-east China, and phases of the Yang-shao culture of central China. One strange and unexplained fact was that the Hung-shan grave pottery was constructed without bottoms, indicating a deliberately ceremonial function.[16]

Feasting, and the provision of banquets for both the living and the dead, have continued as an important ritual in Chinese life down to modern times. Jessica Rawson conjectures that the preparation of ritual meals for the deceased was probably in use by the Neolithic, using as demonstration fine ceramics buried in large numbers in Ta-wen-khou 大汶口 culture tombs, around –3,000 and earlier. Such tombs, located in Shantung province 山東省, contained sets of between six and twenty elegant, burnished cups on tall feet, that were placed on, in and around coffins.

[10] The exhibits are so-labelled in Pan-pho museum, but so far no published analytical research confirms the question of temper.

[11] Cf. Yang-shao ceramics of Pan-shan 半山 type from eastern Kansu province 甘肅省, examined for their construction by optical microscopy and xeroradiography by Vandiver (1988 and 1989b), and the discussion of her findings on pp. 382–8 of this book.

[12] Chao Wen-I & Sung Pheng (1994), pp. 45–6, 86.

[13] Nelson (1995), p. 28.

[14] *Ibid.*, pp. 38–9.

[15] Anon. (1986c), pp. 1–17.

[16] Nelson (1995), p. 21.

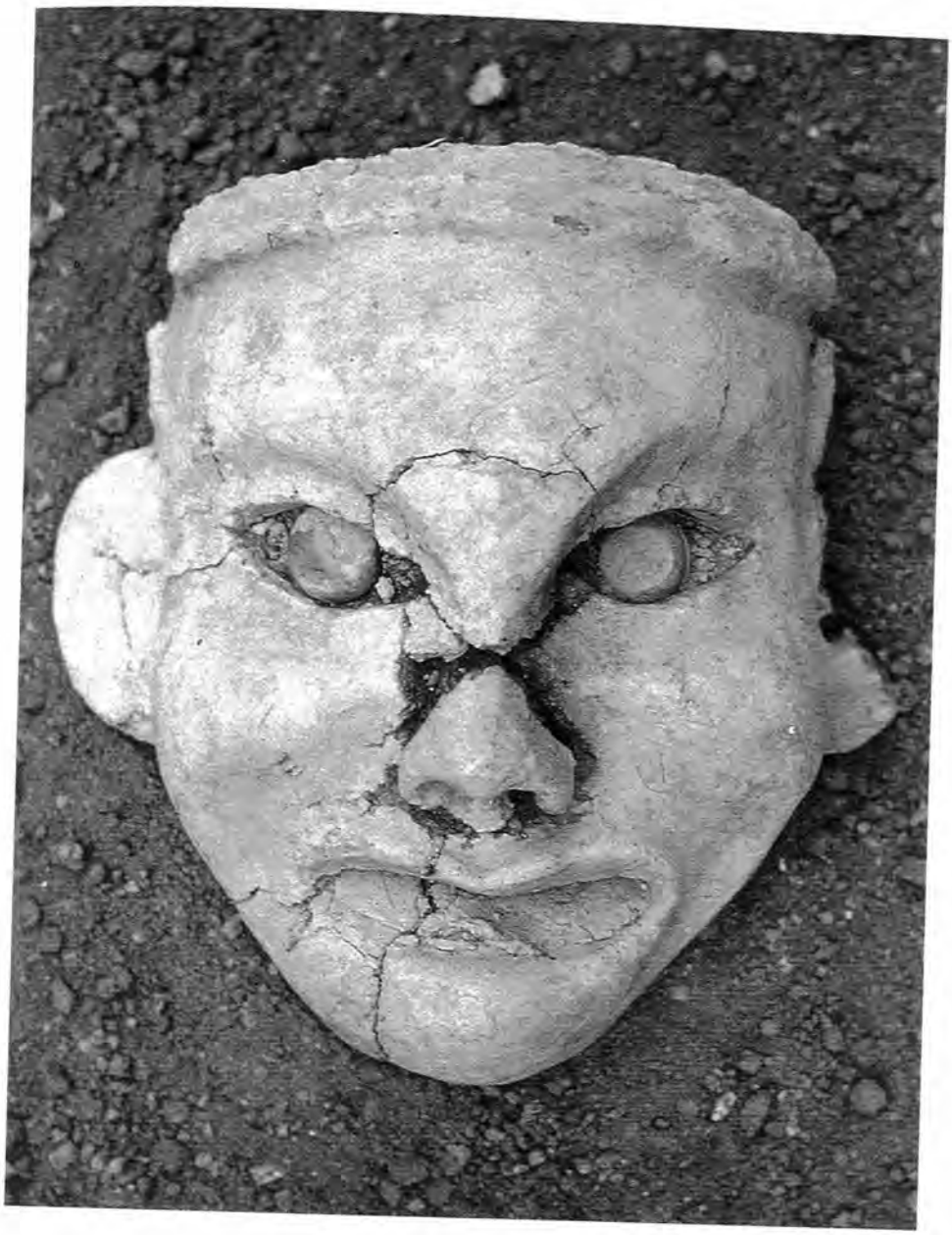


Fig. 3 Model of a human head from Niu-ho-liang

Rawson suggests that these indicate the ritual offering of wine in fine ritual vessels, along with food, by the living to their dead relatives.[17]

This very brief survey of three Neolithic cultures suggests what more detailed studies have confirmed, namely that in the Neolithic period status materials comprised stone (particularly jade), shells (which were often used as currency) and certain types of fine ceramic. What we cannot determine is the relative status enjoyed by cloth and clothing. Numerous finds of pottery and bone spindle-whorls, the excavation of woven silk fragments[18] and multiple impressions of woven cloth left in the clay of ceramic vessels, suggest that textile technology was relatively advanced in the Neolithic.[19] What we know about Chinese textiles and fashion in later periods (and indeed, what we may infer from our own cultural experiences, where textiles and fashion play a dominant role), suggests that cloth may have enjoyed high status in ancient China.

Bronze Age

The notion of a 'Bronze Age' is a modern concept, and although it is accepted by +20th- to 21st-century historians and archaeologists in China, it is commonplace for them to refer to ancient history in dynastic terms. Many experts accept the existence of three phases: the Hsia dynasty 夏代 (traditional dates –21st to –16th centuries), the Shang dynasty 商代 (*c.* –16th century to *c.* –1,050) and the Chou dynasty 周代 (*c.* –1,050 to –221).[20] The advent of the Bronze Age brought two, new important cultural components. The first was the widespread use of metal for high-status objects, such as ceremonial and feasting vessels; the second, the promulgation of written texts, in which information on material culture and its accoutrements were recorded.

So far as the archaeological record is concerned, some of the earliest bronze vessels so far discovered come from the site of Erh-li-thou 二里頭 in Honan province, dating to about –2,000 to –1,500.[21] Some Chinese archaeologists assign this site to the Hsia dynasty, and quantities of fine ceramics have also been excavated there, whose forms relate to metal.[22] Indeed, at both this and at subsequent mid and late Shang dynasty sites such as Cheng-chou 鄭州 and An-yang 安陽 in Honan province, two common bronze forms have been shown to depend on earlier ceramics: tripods and vessels with high, circular ring feet. Robert Bagley has characterised the relationship thus:[23]

[17] Rawson (1999), p. 41.
[18] Wilson (1993), p. 133.
[19] See Kuhn (1988), pp. 61, 90–141, 157.
[20] The Hsia dynasty is still in contention; some scholars accept its historicity and others do not.
[21] Rawson (1980), p. 42; Barnes (1993), p. 119.
[22] See Anon. (1974a), pp. 234–48, pls. 2–5.
[23] Bagley (1987), pp. 24–5.

these shapes cannot be said to owe much to the founder's technique, for they were mostly inherited from an earlier stage . . . These distinctive pottery shapes came ultimately from the very ancient Neolithic tradition of the east coast, where . . . the wonderfully impractical shapes of pottery vessels deposited in (the same) graves hint at a ritual purpose similar to that served by the bronzes.

In addition to form, ceramics can also be ranked in terms of their body-material. During the late Shang dynasty a fine, white-bodied ceramic appeared; this was a royal ware, and its manufacture was carried out at the capital, An-yang, a city that flourished between about −1,300 and −1,050. The body-material of these wares, somewhere mid-way between a fine white stoneware and a porcelain, has been shown through analysis to be made from lower-grade secondary kaolins, fired to the 1,050°C to 1,150°C temperature range.[24] Their composition suggests that the raw material came from similar sources as later high-fired, glazed whitewares such as those from Kung-hsien 鞏縣 in Honan province.[25] The form and decoration of Shang dynasty whitewares were refined and closely related to bronze ritual vessels (see also pp. 102–3, 114).

Excavations at many Bronze Age city sites revealed designated areas of workshops dedicated to the manufacture of pottery.[26] For example, at Cheng-chou separate workshops for ceramics, bronze-casting and bone-carving were situated outside the city wall, with fourteen kilns to the south-east of the site and a clay preparation area to the west.[27] This supports textual information that ceramic manufacture was a recognised profession, practised by skilled craftsmen.

Archaeology has also indicated that during the high Bronze Age, i.e. the Shang and early Western Chou periods, status materials comprised jade, horn, ivory, stone, lacquer, textiles and bronze. Jessica Rawson has pointed out that ceremonial vessels were cast in bronze, and that ceramic was only used for the manufacture of cheaper imitations sets for burial.[28] She has also drawn attention to a curious and sweeping change that took place at the end of the middle Western Chou period (−9th century), when a suggested revision to ritual practice led to the abandonment of old vessel types, and the adoption of new forms based on ceramic vessels.[29] The unusual nature of this reversion, to the copying of a cheap material (ceramic) in a costly material (bronze), is noteworthy. It is perhaps worth considering what types of pottery were available to consumers at that time, and attempting to severalise different qualities of ceramic. But first ceramic types themselves should be distinguished one from another.

[24] Sundius (1959), pp. 107–23.
[25] Wood (1992), p. 147.
[26] Chang Kwang-Chih (1963, 1986), pp. 362–3. For Cheng-chou, see An Chin-Huai (1960), p. 70.
[27] Treistman (1972), p. 77.
[28] Rawson (1990), p. 108 and note 206.
[29] *Ibid.*, pp. 108–9.

CERAMIC TYPES AND CHINESE TERMS

In the modern English language, ceramics can be categorised by their body-material as earthenware, stoneware or porcelain. Porcelain has been described as:[30]

> A vitrified, white and translucent ware . . . that is fired at 1,300°C plus. The name porcelain is said to have been coined by Marco Polo in the 13th century from *porcelino*. This was the name of the translucent cowrie shell which looked like a little pig or porcelino. He likened Chinese porcelain to this translucent white shell.

In fact, Chinese porcelain may not necessarily be either white or translucent. Porcelain stones and clays can contain impurities such as iron oxide, which discolour them to brown or grey or yellow in their raw state, and cause a grey tone after firing. Moreover, if an object is thickly potted it will not conduct light through its walls. Even the firing temperature varies in the range 1,150–1,400°C (see pp. 55–60).

Stoneware has been characterised as a hard, strong and vitrified ware, fired above 1,200°C, in which the body and glaze mature to form an integrated body-glaze layer.[31] Earthenware has been characterised as having a porous body that can be waterproofed by glaze, and the simplest distinction between stoneware and earthenware as being:[32]

> the porosity of the body. If the fired body has a porosity of more than 5%, then it is earthenware. Many potters add to this criterion of porosity a consideration of the temperature at which the glaze is fixed. The softer temperatures below 1,100°C . . . are associated with earthenware glazes . . .

If this terminology of earthenware, stoneware and porcelain is accepted, then in broad terms the history of China's earthenware begins in the Palaeolithic, of stoneware early in the Bronze Age, and of porcelain in the late +6th century. There are two problems, however, in the distinctions outlined above. The first is a technological consideration, the second a linguistic dilemma.

In the first place, many stonewares in China (particularly in the north) fall into the 'earthenware' porosity range, because of the refractoriness of their raw materials.[33] For most (but not all) Chinese wares the deciding difference between earthenware and stoneware can only be marked by the significant development of *mullite* crystals in their ceramic body (a full discussion of the development of mullite is on p. 59). This is a factor that can only be determined by microscopy, and not by the naked eye.

[30] Hamer & Hamer (1975), p. 229.
[31] *Ibid.*, p. 285.
[32] *Ibid.*, p. 111.
[33] Porosity is a vague term if a distinction is not made between 'open' and 'closed' porosity (also called 'apparent' and 'true' porosity). Many Chinese stonewares have percentage water absorption greater than 5%: for example, Ju ware 汝窯 19.3%; Chün ware 鈞窯 10.7%; Lin-ju wares 臨汝窯 up to 8%. A full account of standard industrial ceramic investigation into Chinese ceramics, including porosity, is detailed in Palmgren, Sundius & Steger (1963), pp. 452–75.

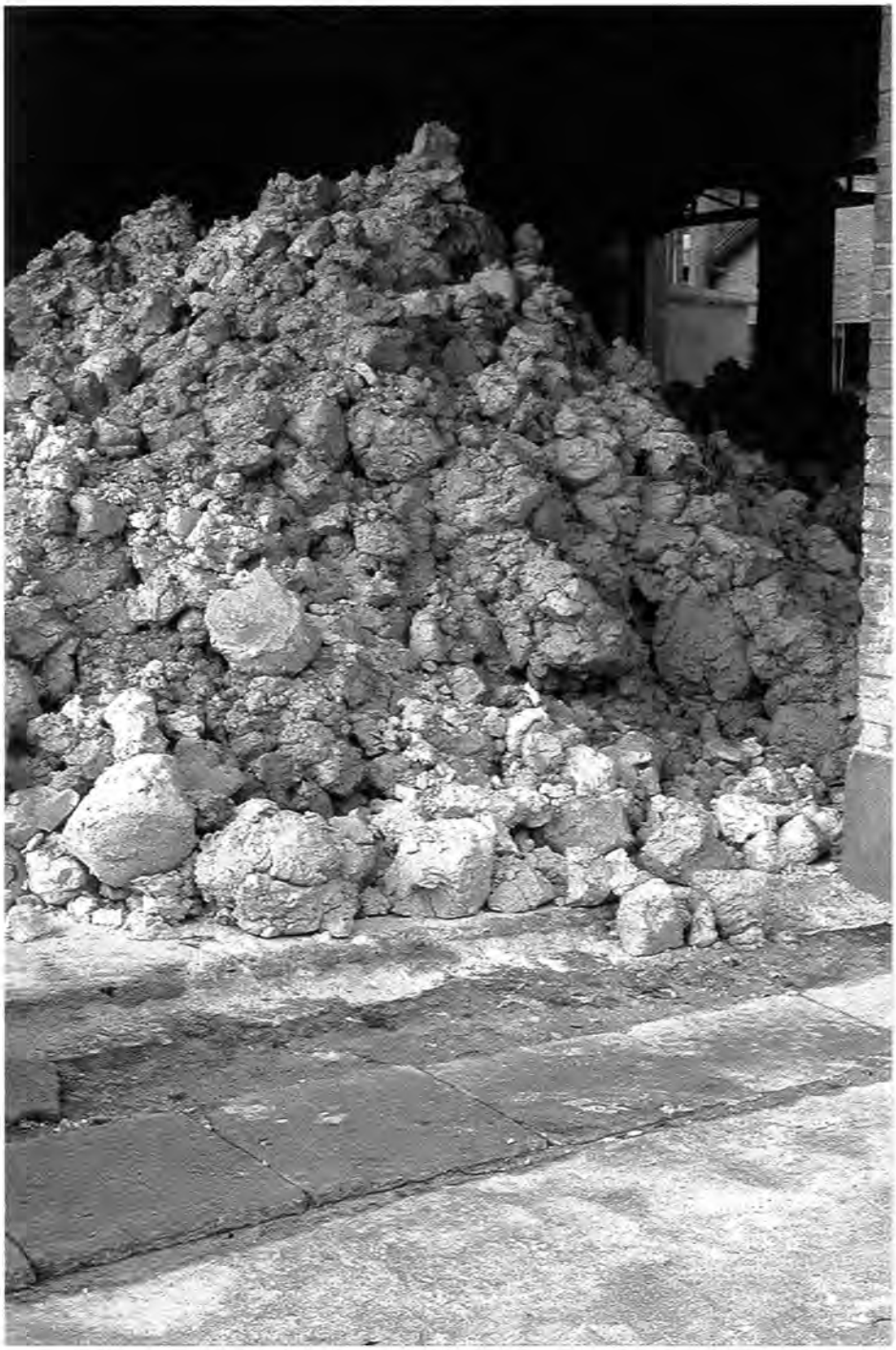


Fig. 4 Porcelain clays at Ching-te-chen (+1982) to show the range of colours

In linguistic terms also, Chinese criteria for porcelain, stoneware and earthenware differ from the tripartite system described above. Etymologically speaking, modern Chinese language divides ceramics into only two types, *thao* 陶 and *tzhu* 瓷. The lower-fired *thao* material corresponds to English earthenware and some categories of stoneware, whereas high-fired *tzhu* equates to both stoneware and porcelain. In translations from Chinese into Western languages, one may thus encounter material that we would regard as stoneware, described as 'porcelain'.

In classical texts the term *wa* 瓦, which in modern terminology is used for tiles, was used for ceramics generally. Although high-fired stonewares were made as early as the Shang dynasty, there does not seem to have been any special descriptive term for them in early times. The character *tzhu* did not come into general use until the Sui dynasty, though it did occur once or twice in Han and Chin dynasty texts. It first appeared in an ode written by Tsou Yang 鄒陽 in the reign of Emperor Wu 武帝 (–140 to –88).[34] Although the great Later Han dictionary *Shuo Wen Chieh Tzu* (Analytical Dictionary of Characters, +121) did not include the word, by the +3rd century the poet Phan Yüeh 潘岳 (+247–300) was using the term 'bright porcelain' (*phiao-tzhu* 縹瓷) to describe a pale-green celadon wine vessel.[35] From the time that *tzhu* was defined, *thao* and *wa* were seen to be less prestigious materials.[36]

Neolithic pottery can all be classified as *thao*, as can the unglazed sets of burial vessels in bronze forms mentioned above. The manufacture in the Shang dynasty of a higher-quality, unglazed, white-bodied ceramic that was fired to low stoneware temperatures has been noted. The middle and late Shang also saw the appearance of the first high-fired and glazed ceramic that later would be classified as *tzhu*. This grey-bodied, thin-walled ceramic was finely finished, and was distinguished by the deliberate addition of glaze.[37] Originally derived from accidental fly-ash glazing from the kiln, the even surface appearance of many Shang and Western Chou dynasty glazed vessels indicates that the glazing process was deliberate. Such pieces have been found at many sites in central China, and at one or two sites in the north. In a seminal paper delivered to a symposium on the Science and Technology of Ancient Ceramics in Shanghai in November 1995,[38] Chen Tiemei [Chhen Thieh-Mei 陳鐵梅] of the archaeology department at Peking University described results obtained from 93 samples taken from five Shang dynasty sites: Cheng-chou in Honan province, Phan-lung-chheng 盤龍城 in Hupei 湖北, Chiang-shan 江山 in Chekiang 浙江, Chiao-shan 角山 in Chiangsi and Wu-chheng 吳城 in Chiangsi.[39] Neutron activation analysis revealed that low-fired wares (*thao*) were different at each of the five sites, indicating local production. High-fired greenwares, however, were near- identical in their composition at all sites, and

[34] *Han Shu*, ch. 19, p. 7. See Li Chhiao-Phing (1948), p. 69.
[35] *Wen Hsüan*, ch. 18, p. 35.
[36] *Tzhu Hai* (1979), vol. 1, pp. 1002–5; Wang Chhing-Cheng (1982), pp. 188–9.
[37] Such wares have sometimes been termed 'proto-porcelain' by Western authors.
[38] The paper, a joint research project with the University of Wisconsin, was published in Chen Tiemei *et al.* (1999a) and Chen Tiemei *et al.* (1999b).
[39] For comparative studies of this material, see Li Jiazhi *et al.* (1992).

statistical and chemical analyses indicated their common source as being Wu-chheng, Chiangsi province.[40] The fact that good-quality, high-fired, glazed ceramics were traded from one centre of production to sites as far afield as Cheng-chou in northern China, indicates the value attached to such products.

EARLY HISTORIOGRAPHY OF CHINESE CERAMICS

As far as early texts are concerned, late Bronze Age scholars sought to schematise the very beginnings of Chinese history into three cycles, with recognisable leaders. Thus the Three Sovereigns (Fu Hsi 伏羲, Shen Nung 神農 and Chu Jung 祝融) were succeeded by the Five Emperors, and then by the Three Dynasties of Hsia, Shang and Chou.[41] References make it clear that pottery-making began in the legendary period of the Three Sovereigns, and that it was as important an occupation as fishing, the making of stone weapons, and farming (the occupations of Shen Nung).[42] In the time of the Five Emperors, the Yellow Emperor (Huang Ti 黃帝) established an office called *Thao Cheng* 陶正 (Regulator for Pottery), Shao Hao 少皓 emphasised the importance of potting (*thuan-chih* 摶埴),[43] while the surname *Thao* 陶 (potter) was one of the earliest names to appear, during the reign of Yao 堯, the last-but-one ruler before the Hsia dynasty.[44] Yao's successor Shun 舜 made fine pottery on the banks of the Yellow river 黃河,[45] improving the quality of coarse ceramics of the eastern tribesmen (*Tung I* 東夷) of whom he was a member and thus saving it from failure.[46]

The Legalist philosopher Han Fei Tzu 韓非子 (*d.* –233) traced a slow decline brought about by extravagance, from the time of Yao to the Shang [Yin 殷] dynasty. He used the control of pottery-making for court ritual vessels as an example:[47]

> Yao . . . ate from clay vessels and drank from clay mugs . . . Shun . . . accepted and manufactured vessels from wood by cutting down trees . . . he lacquered them black and used them in palaces . . . Yu had ritual vessels made with the outside painted black and the

[40] No samples from Chekiang province were used in the study, so while a southern source is undoubted, Wu-chheng should not be assumed to be the sole source for all Shang dynasty glazed wares found in the north.

[41] Chang Kwang-Chih (1963, 1986), p. 305. This is the schema presented in *Chou Li*, compiled in the Former Han dynasty but incorporating some late Chou dynasty material.

[42] *I Chou Shu* ('*I Wen*'), 'the lost text' in 'The Lost Book of Chou'. *Shih Chi* ('*Wu Ti Chi*') section.

[43] *Chou Li Chu Shu*, ch. 39, p. 11.

[44] The surname Thao occurs in the Thao-thang clan 陶唐氏, which Yao married into. Yao's successor Shun married into the Yu-yü clan 有虞氏, who excelled in pottery-making. *Chou Li*, ch. 6 ('*Tung Kuan*'), pp. 77–8.

[45] *Shih Chi* ('*Wu Ti Pen Chi*'), p. 32. *Meng Tzu*, bk. 3, ch. 8, mentions Shun's activities as a potter. *Chou Li Chu Shu*, ch. 39, p. 11. Shun was described as farming at Mount Li 曆山, located near the confluence of the Fen 汾河 and Yellow rivers in south-west Shansi province 山西省. He made pottery about twenty miles north, near the Thang dynasty town of Thao-chheng 陶城 [lit. 'Potters' Town']. See Nienhauser (1994), p. 11, notes 123 and 126.

[46] *Shuo Yüan*, ch. 20, p. 2. This reference is one of many to link ideas of moral teaching and improvement with the medium of pottery-making. *Meng Tzu*, bk. 8, ch. 1, mentions Shun's origins.

[47] *Han Fei Tzu* '*Shih Kuo*' ('10 errors'), no. 6, reproduced in Liang Chhi-Hsiung (1960), vol. 1, p. 74. The quote is partially used in Chang Kwang-Chih (1963, 1986), p. 4.

inside decorated in red . . . but 33 states would not submit to him . . . the Yin people . . . engraved vessels for meals and incised wine vessels . . . but 53 states would not submit.

堯 . . . 飯於土簋, 飲於土鉶 . . . 舜 . . . 作爲食器, 斬山木而財之 . . . 流漆黑其上, 輸之於宮 . . . 禹作爲祭器, 黑漆其外而朱畫其內 . . . 而國之不服者三十三 . . . 殷人 . . . 食器雕琢, 觴酌刻鏤 . . . 而國之不服者五十三.

Lü Shih Chhun Chhiu (Master Lu's Spring and Autumn Annals, −239) referred to pottery in the time of Yu the Great 大禹 (founder of the Hsia dynasty), to ceramic manufacture along the bank of the Yellow river, and to the making of pottery by the Khun-wu 昆吾 tribesmen.[48] *Han Shu* (History of the Former Han Dynasty, *c.*+100) in its section on geography, identifies the Khun-wu as being descended from Hsia nobility, and originating in a small kingdom that was probably located north-east of present-day Lan-thien 藍田 in Shensi province.[49]

Of the Five Classics of China,[50] the *Shu Ching* (Book of Documents), contains a section called 'the Books of Hsia', which historians judge to have been written in the −4th to −3rd centuries.[51] This section deals with the opening up of early China to agriculture, and the suitability of conditions in different regions. Among other considerations is the character of different soils, and of interest to us in relation to pottery-making are descriptions of the earth in China's historic heartland. Thus, for example, the district of Chi-chou 冀州 (equivalent to Hopei, Shansi and parts of Honan and Shensi provinces) had soil defined as 'pale and powdery soft', a fair description of wind-deposited loess; while that of Yen-chou 兗州 (equivalent to parts of Shantung, Honan and southern Hopei provinces) had soil that was 'dark and rich' which suggests water-worked alluvial loess and silt.[52]

Another of the Five Classics, the *Shih Ching* (Book of Odes), contains poetry believed by scholars to date back to between −1,000 and −600.[53] Many of the odes concern feasting and making merry, with descriptions of eating and drinking vessels. It is interesting that ceramic is rarely mentioned. Thus for example drinking cups made of curving horn, jade and dried gourd are noteworthy,[54] while large food baskets and dishes of wood and bamboo (*pien-tou* 籩豆) and round bamboo vessels with two handles (*kuei* 簋) are prominent.[55] One of the classics on etiquette, the *I Li*,

[48] *Lü Shih Chhun Chhiu*, ch. 5:5, p. 27; ch. 14, p. 78; ch. 17:2, p. 101.

[49] *Han Shu* ('*Ti Li Chih*'), ch. 28.2, p. 28b. Chu Yen mentions the Khun-wu in *Thao Shuo*, ch. 2, p. 1a, citing as reference sources *Lü Shih Chhun Chhiu* and *Shuo Wen*.

[50] The Five Classics are the *I Ching* (Book of Changes); the *Shu Ching* (Book of Documents); *Shih Ching* (Book of Odes); the books on ritual *Chou Li* (Chou Ritual), *I Li* (Book of Etiquette and Ceremonial), *Li Chi* (Book of Rites); and *Chhun Chhiu* (Spring and Autumn Annals).

[51] Shaughnessy (1993a), pp. 376–86.

[52] *Shu Ching* ('*Hsia Shu*', '*Yü Kung*' 1), pp. 7 and 17. Legge (1865), vol. 1, p. 97. Karlgren (1950), pp. 12–15.

[53] Loewe (1993b), p. 415.

[54] *Shih Ching, Hsiao Ya* ('*Sang Hu Chih Shen*'), no. 1 *Sang Hu*; *Ta Ya* ('*Sheng Min Chih Shen*'), no. 6 *Kung Liu*; *Ta Ya* ('*Thang Chih Sheng*'), no. 8 *Chiang Han*. Legge (1931), pp. 295, 373, 422. Waley (1937), pp. 245, 133. Karlgren (1944), pp. 249–50.

[55] *Shih Ching, Kuo Feng* ('*Chhin Feng*'), no. 10 *Chhüan Yü*; *Kuo Feng* ('*Pin Feng*'), no. 5 *Fa Kʻo*; *Hsiao Ya* ('*Sang Hu Chih Shen*'), no. 6 *Pin Chih Chhu Yen*; *Hsiao Ya* ('*Lu Ming Chih Shen*'), no. 5 *Fa Mu*; *Hsiao Ya* ('*Hsiao Min Chih Shen*'), no. 9 *Ta Tung*; *Ta Ya* ('*Sheng Min Chih Shen*'), no. 1 *Sheng Min*; *Lu Sung* ('*Ma Chih Shen*'), no. 4 *Pi Kung*. Legge (1931), pp. 150, 179, 295, 190–1, 268, 362, 474. Waley (1937), pp. 312, 295, 205, 318, 243, 271. Karlgren (1944), pp. 251–2, 223, 242–3, 213, 221.

or 'Book of Ceremonials and Rituals', confirms the seeming lack of importance of ceramics in ritual. Composed from a corpus of material that may have its origins as early as the –6th century,[56] the *I Li* describes a range of vessels in common use such as wood and bamboo stands and containers (*pien-tou* again), cup baskets, ivory drinking cups, horn goblets and bronze vessels.[57] There are very few direct references to ceramics. One such occurs in the chapter on 'The Ritual Banquet', when the host, a high-ranking duke, is allotted wine-containers consisting of a pair of earthenware pots and stands covered with fine or coarse cloth according to season.[58] In the glossary to this section, however, it states that these ceramic jars dated to the period of Yu the Great (legendary founder of the Hsia dynasty), i.e. legendary antiquity. The value of the wine jars was not to do with their ceramic material, therefore, but rather with their status as antiques. Further information may be gleaned from the *I Li* by virtue of what is *not* included in the text. So, for example, in the section on ceremonial missions between rulers of states, official tributes included animal furs and hides, horses, bundles of silks and brocades, sets of animals including oxen, sheep and pigs, painted lacquer food containers filled with choice food delicacies and bronze vessels. Ceremonial jade *kuei* 圭, *chang* 璋, *pi* 璧 and *tshung* 琮 were carried by mission officials.[59] Ceramics were not mentioned.

Though ceramics may not have been valued as luxury objects worth mentioning in official writings, they seem not to have been used as a matter of course by commoners in the –1st millennium. We have seen that wooden, bamboo and gourd vessels were used in ceremony, and it is likely that these humble and easily obtainable natural materials were also utilised by the populace. Indeed, no less an authority than Confucius commended their use. Lamenting the early death of his favourite disciple Yen Hui 顏回 in –490, he wrote:[60]

> Virtuous indeed was Yen Hui! A single bamboo bowl of millet to eat, a gourdful of plain water to drink, and living in a shabby back alley – such living conditions others would have found unendurably depressing, but Yen Hui's optimism remained unaffected.
>
> 賢哉, 回也! 一簞食, 一瓢飲, 在陋巷, 人不堪其憂, 回也不改其樂. 賢哉, 回也!

Although the literary record subsumed a mixture of oral history, myth and later scholarly gloss, it nonetheless indicated a clear pattern for China's earliest history. The official status of ceramic manufacture was already well established by the onset of the Bronze Age. By the Chou dynasty pottery manufacture was recognised as one of the key official professions, its organisation described in a section of *Chou Li* called *Khao Kung Chi* (The Artificers' Record), written *c.* –500 to –450. A discussion of the

[56] A likely supposition is that the extant *I Li* is part of a much larger group of materials that may date back to Confucius' time (–551 to –479). See Boltz (1993b), p. 237.

[57] *I Li*, phien 1 ('*Shih Kuan Li*'), ch. 1, pp. 11a, 17a-b; phien 2 ('*Shih Hun Li*'), ch. 2, p. 12a; phien 7 ('*Ta She*'), ch. 21, pp. 13b, 15a-b. Steele (1917), pp. 4, 8, 21, 158, 160, 189, 267.

[58] *I Li*, phien 6 ('*Yen Li*'), ch. 20, p. 2a. Steele (1917), pp. 122, 278.

[59] *I Li*, phien 8 ('*Pin Li*'), ch. 20, pp. 1a–38b. Steele (1917), pp. 189–227.

[60] *Lun Yü*, bk. 6 ('*Yung Yeh*'), ch. 11.

text occurs on pp. 405–6. *Khao Kung Chi* was composed towards the end of the Chou dynasty in the early Warring States period, a time when Chinese society was undergoing great social, political and economic changes. Excavated artefactual evidence, in the form of inscribed pottery state seals and ceremonial vessels, showed that specialist ceramic workshops served the rulers of the various states. Although terminology was not consistent, inscriptions comprehended the names of pottery officials including those of senior rank.[61] Hierarchical management of the state pottery industry was standardised in the succeeding Chhin and Han dynasties, as was evidenced by inscriptions on architectural ceramics (see below and pp. 410–11, 499).

CHHIN AND HAN PERIODS

Just prior to the Western Han dynasty in the -3^{rd} century, the moral philosopher Mencius 孟子 engaged in debate with a reformer called Pai Kuei 白圭. Their discourse concerned tax, but incidentally revealed the importance of pots in everyday life. Pai asked if taxing to a total of one-twentieth of produce would be ethical. Mencius replied that this would put Pai on a par with itinerant, barbarian tribesmen. Could 10,000 families manage with only one potter to supply their needs? Sheepishly, Pai conceded that they would not have enough vessels for use.[62]

By the Eastern Chou period the ceramic industry had been systematised so that certain types of ceramics such as ritual vessels and architectural materials were made in government-controlled workshops. By the Chhin dynasty evidence of ceramic workshop management, including military supervision and the employment of convicted criminals as corvée labour, comes from excavated stamped pottery and seals, found at the Chhin dynasty capital at Hsien-yang 咸陽, the burial site of Shih-Huang-Ti, First Emperor of the Chhin 秦始皇帝, and at Western Han sites in Honan, Hopei and Shansi provinces (see pp. 410–14).[63] The regulation of state-controlled manufacture was confirmed in *Li Chi*, where managers were ordered to inspect sacrificial vessels at first hand, and to make sure that each was correctly marked with its maker's name to ensure quality-control.[64]

Nevertheless, though ceramics were necessary to society (to the extent of being mass-produced under official supervision), they do not seem to have been especially valuable products. Two accounts (from among many) illustrate the low status of ceramics during the Han dynasty. The first concerns the pious and frugal Emperor Wen 文帝, who ruled from −179 to −157, the ruler who instigated the practices of ploughing for the emperor and silk-worm rearing for the empress, and who worried about famine and honest occupations for his people. He is remembered as an

[61] Li Hsüeh-Chhin (1992), pp. 170–3.
[62] *Meng Tzu*, bk. 6, ch. 10: '白圭曰: 吾欲二十而取一, 何如. 孟子曰: 子之道, 貉道也. 萬室之國一人陶則可乎. 曰: 不可器不足用也'.
[63] Yüan Chung-I & Chheng Hsüeh-Hua (1980), pp. 83–9; Yü Wei-Chhao (1963), pp. 34–8; Wang Chhing-Cheng (1982), pp. 146–7.
[64] *Li Chi*, phien 4 ('*Yüeh Ling*'), ch. 1, p. 8a. Cf. Wen Jen-Chün (1987), p. 97.

honest and diligent ruler, who kept the empire in good order without overt corruption, conspicuous consumption or the threat of war.[65] During his lifetime he followed custom by constructing and furnishing his own tomb, the Pa Ling 霸陵, outside Sian. Instead of constructing an artificial burial mound he utilised a natural hill for his tumulus.[66] The tomb has not been excavated, but we know something of its contents from the Han histories. As an example of frugality and humility to his people, Emperor Wen eschewed expensive trappings. He forbade the inclusion of gold, silver, copper and tin artefacts and instead commanded that his sepulchre be furnished with objects made from pottery.[67]

Another piece of evidence concerns Thang Tsun 唐尊, who was promoted to Grand Tutor by the usurper Wang Mang 王莽 in +20. Like many hypocritical politicians then and since, Grand Tutor Thang Tsun made a play for popular appeal by expressing solidarity with the people. His piety was expressed by wearing simple clothes, by riding in a common soldier's chariot drawn by mares,[68] by sleeping on a straw bed, by eating from earthenware (*wa* 瓦) dishes and by using simple earthenware dishes to send food gifts to other ministers.[69]

The status of ceramics in China was not a constant. The Han period ended in chaos and warfare that caused many educated northerners to flee south. Mass migrations from the north opened up new territories in the south, and advances in technology led to a slow rise in ceramic prestige. The arrival of Buddhism contributed to a hierarchy of ritual vessels that no longer privileged bronze and lacquer, and led to ceramics gaining status that they had last enjoyed in the Neolithic period.[70] Official units were established to co-ordinate the supply of ceramics from the best kilns to court. By the +9th century top-quality celadons from the south and white porcelain from the north had gained the ultimate accolade of becoming imperial tribute ware.

THE STATUS OF POTTERS

A related but not identical theme was the status of potters in China, as distinct from the status of the ceramics they produced. In this context, special products made for the aristocracy should be distinguished from pottery made in towns and villages across China for the populace. As far as the former is concerned, the creation of high-status ceramics in the Neolithic, including those made for special feasting, worship and burial, has already been mentioned. By the early Shang dynasty, at

[65] An example of his good ordinance is the establishment of bronze tiger credentials for the Administrators of his Commanderies in −178, to prove their status and to counteract fraud and treachery. *Han Shu* ('*Wen Ti Chi*'), ch. 4, p. 11a. Dubs (1938), vol. 1, p. 245.

[66] Thorp (1987), p. 22.

[67] *Han Shu* ('*Wen Ti Chi*'), ch. 4, p. 21b. Dubs (1938), vol. 1, p. 273.

[68] Mares were seen as taboo animals, due to an ancient association with the earth goddess, see Dubs (1938), vol. 3, p. 402.

[69] *Han Shu* ('*Wang Mang Chüan*'), ch. 99, p. 12a.

[70] Vainker (1991), p. 49.

Erh-li-thou, ceramics were manufactured in separate areas to the main buildings and palaces,[71] and during the Shang specialised craft production ensured the supply of distinctive products for the elite. By the Western Chou period skilled craftsmen were conscripted from a wide area to serve the aristocracy. These skilled workers were augmented by slave labour, their products overseen by officials in official workshops.[72] *Khao Kung Chi* in *Chou Li* described the specialised manufacture of ritual vessels in the -5^{th} century, listing regulations that indicated the involvement of master potters and supervisory managers.[73] In the Warring States period, three levels of production have been described: that controlled by central government, that controlled by local government, and that managed as private industry.[74]

Governmental offices responsible for manufacturing bricks and tiles were firmly established by the Chhin period, controlled by the Chamberlain for Palace Revenues (*Shao-fu* 少府.) and the Director of the Directorate for the Palace Buildings (*Ta-chiang* 大匠), among other officers (see pp. 410–11).[75] Official supervision continued in the Han period, managed by personnel such as the Chamberlain for Palace Buildings (*Chiang-tso Ta-chiang* 將作大匠) and the Aide to the Pottery Office (*Chen-kuan Chheng* 甄官承).[76]

In attempting to describe the majority of potters, who were connected with small-scale family workshop production outside the central government-controlled system, anthropological models are perhaps helpful in determining status. Chinese historians have posited that women were likely to have taken principal control of ceramic-making in the early Neolithic period. They base their view on comparable stages of social development among contemporary minority tribes in south-west China and in Taiwan 臺灣 (see pp. 284–7 for a discussion of pottery-making techniques in Yunnan province 雲南省). As society developed, the activity was gradually taken over by men.[77] This essentially Marxist theory of early matriarchal society has some parallels with the views of Western anthropologists, based on fieldwork. Dean Arnold, for example, investigating ceramic technology in South America, observed that pottery-making was scheduled so as not to interfere with other subsistence activities, and that the most basic level of manufacture in households was often carried out by women. As household manufacture developed into industry with specialised production, stage two in his model of development was reached, when both men and women were involved in the work. The third stage of development was marked by workshop industry, and the emergence of pottery-making as

[71] Anon. (1965), pp. 215–24; Anon. (1974a), pp. 247–8.

[72] The skilled and slave labour force was known as *pai-kung* 百工 '100 craft skills'. Feng Hsien-Ming *et al.* (1982), pp. 54–5.

[73] Wang Chhing-Cheng (1982), pp. 188–9; Wen Jen-Chün (1987), pp. 123–38.

[74] Feng Hsien-Ming *et al.* (1982), p. 107. For general discussion of government workshops see Needham & Wang (1965), pp. 18–20; and for those workshops involving architecture Needham *et al.* (1971), p. 89. For discussion of official workshop manufacture occurring alongside household production see Underhill (2002), pp. 4–6, 231–5.

[75] Yüan Chung-I & Chheng Hsüeh-Hua (1980), pp. 83–92.

[76] Huang Pen-Chi (1965), p. 82; Hucker (1985), pp. 140–1, 121, 125.

[77] Feng Hsien-Ming *et al.* (1982), p. 2.

a full-time occupation.[78] Although a direct comparison between South America and China cannot be made, broad analogies can be noted. Thus by the middle Neolithic period, areas within settlements were already devoted to pottery-making, the second level of activity outlined by Arnold, while by the Bronze Age his third stage of development had been attained.[79]

Hierarchies based on social status were recorded in the Chou dynasty, though it is likely that they existed for several millennia prior to that time. By the Warring States period tentative hierarchies based on occupation were described, and these became fixed by the early Former Han dynasty.[80] The traditional formulation is '*shih, nung, kung, shang* 士, 農, 工, 商'; 'scholar, farmer, artisan, merchant', in order of rank from 'scholar' downwards. Derk Bodde has written that during the Chou period the distinction was made that scholars and farmers were of higher rank than artisans and merchants; but that there was no marked bias in favour of artisans over merchants. By the Han dynasty the standard sequence of scholar, farmer, artisan, merchant had assumed its final form, and the prestige of merchants had dropped sharply below that of artisans.[81] Skilled pottery workers were thus valued above men who earned a livelihood in trade. Nevertheless, both occupations were viewed with some suspicion by intellectuals, and by the ruling class. The fourth emperor of Western Han, Emperor Wen, established the symbolic ceremony of ploughing to provide millet and grain offerings for the imperial ancestral temple in –178.[82] In –167 the empress was encouraged to raise silk-worms for sacrificial clothing,[83] and both activities were deemed to be traditional imperial activities. Their original purpose was to combat an inordinate fear that the populace was turning away from the basic businesses of food and cloth production, towards more lucrative but non-productive businesses. In terms of pottery, an analogy could be made between the manufacture of vessels essential to daily cooking and eating, and those created for luxury. Emperor Wen himself issued an edict in –163, that noted his concern about famine and the lack of food production, and asked how his subjects could possibly devote themselves to unimportant activities (i.e. craft and commerce), thereby multiplying the number of people injuring agriculture.[84] In –142, succeeding Emperor Ching 景帝 issued an imperial edict stating that the production of carved ornaments and chiselled engravings injured agriculture, while the manufacture of brocade, and embroidered and braided silk ribbons, harmed women's work.[85] This was followed in –141 by an edict 'against those who do non-essential things',[86] which

[78] Arnold (1989), pp. 99 and 229.

[79] A much more detailed treatment of the stages of Neolithic pottery development in China, and its specialisations, is provided by Underhill (2002), which was published late in the production schedule for this volume.

[80] Bodde (1991), pp. 203–10, appendix pp. 369–75.

[81] *Ibid.*, pp. 287, 207.

[82] *Han Shu* ('*Wen Ti Chi*'), ch. 4, p. 10a. Dubs (1938), vol. 1, p. 242.

[83] *Han Shu* ('*Wen Ti Chi*'), ch. 4, p. 14b. Dubs (1938), vol. 1, p. 254.

[84] *Han Shu* ('*Wen Ti Chi*'), ch. 4, p. 17a. Dubs (1938), vol. 1, p. 262.

[85] *Han Shu* ('*Ching Ti Chi*'), ch. 5, p. 9b. Dubs (1938), vol. 1, p. 328.

[86] *Han Shu* ('*Ching Ti Chi*'), ch. 5, p. 10b. Dubs (1938), vol. 1, p. 332.

was repeated by Emperor Wu 武帝 in the next reign[87] and by Emperor Chheng 成帝 in –22.[88] This fear and suspicion of craft producers and merchants was accompanied by a string of controlling sumptuary regulations. For example, as early as –199 the first regulation against merchants was enacted, specifying a dress code and prohibiting the carrying of weapons, the riding of horses and the use of ceremonial carriages.[89] Craftspeople and merchants were also taxed on their productions,[90] had little access to education, and were banned from becoming officials.[91]

Outside of government workshops, most Chinese ceramics were without signature, for potters (in common with a large proportion of the populace) were illiterate.[92] Indeed, one could compare the intellectual disdain accorded Chinese artisans, with the Greek Platonic view that human craftspeople were incapable of origination, but had to wait for God to invent the Idea or Form of their products.[93] Domestic ceramic manufacture was regarded as a lowly profession in China. Potters laboured hard to scrape a basic livelihood, and their living conditions were often harsh. Little information about the daily lives of potters in the Han dynasty is available, but described and illustrated circumstances pertaining in the +18th, +19th and +20th centuries do exist, for they were made at a time when Western visitors considered such matters pertinent (pp. 211–12). Of earlier periods, only glimpses can be caught. One such vignette was provided by the Sung dynasty, Neo-Confucian poet Mei Yao-Chhen 梅堯臣, who invoked the image of potters' poverty in verse criticising social disparity and inequality:[94]

> The Potter (+1036)
> Pots cover every inch of space before the door
> But there's not a single tile on the roof.
> Whereas the mansions of those who wouldn't soil their fingers with clay
> Bear tiles overlapping tightly like the scales of a fish
>
> 陶者
> 陶盡門前土
> 屋上無片瓦
> 十指不沾泥
> 鱗鱗居大廈

[87] *Han Shu* ('*Wu Ti Chi*'), ch. 6, p. 17a. Dubs (1938), vol. 2, p. 68.
[88] *Han Shu* ('*Chheng Ti Chi*'), ch. 10, p. 8a. Dubs (1938), vol. 2, p. 392.
[89] *Han Shu* ('*Kao Ti Chi*'), ch. 1b, p. 13b. Dubs (1938), vol. 1, p. 120.
[90] *Han Shu* ('*Liang Huo Chih*'), ch. 24a, p. 3a. Swann (1950), p. 122.
[91] Edicts banning promotion were enacted by the very first Han emperor, see *Yen Thieh Lun*, ch. 1, p. 3a. Gale (1931), p. 9.
[92] The exception was the use of stamped seals used to mark architectural ceramics in the Chhin and Han periods, see pp. 410–11, 499. However, even in these cases the employment of a seal rather than a signature suggests a high level of illiteracy.
[93] Farrington (1966), p. 105.
[94] Nienhauser (1988), p. 621.

Later Texts on Chinese Ceramics

In the period following the Western Han dynasty, a growing body of texts survived to record the history of the Chinese state and the activities of China's peoples. With regard to the production of pottery, a wide selection of books in both Chinese and (later) in Western languages can be used to gather information. It must be said, however, that none of the pre- +19th century literature quoted here, with the exception of the +18th-century writings of the French Jesuit Père Francois Xavier d'Entrecolles, has as its main purpose the investigation of ceramic technology. Some Chinese works, in particular those grouped together under the heading 'Texts Concerned Specifically with Ching-te-chen', contain substantial bodies of information on ceramic manufacture. Other volumes, typified here as 'treatises', 'histories', 'annals' and 'gazetteers', must be gleaned for instruction. By doing so, one runs the danger of selectively quoting small items without regard to the integrity of a larger whole. In spite of the risk it seems worthwhile to indicate uses of a range of sources, in order to augment research based on geology, archaeology and compositional analysis.

The texts have been grouped in a manner consistent with their use as reference authorities for ceramics.[95] It is apparent that this menu does not replicate schemata devised by other scholars in their subject division of source material.[96] It has also been found apposite to discuss texts on architectural ceramic manufacture in the sections devoted to that subject (pp. 104–15, 407–23, 489–522), and to detail further information on Ching-te-chen on pp. 184–213.

Treatises Concerned with Agriculture and Crafts

Books dealing with aspects of rural employment sometimes contained information on ceramics, as part of their broader discourse. Chia Ssu-Hsieh's 賈思勰 *Chhi Min Yao Shu* (Important Arts for the People's Welfare) was an early example, appearing in +533–544. A fuller discussion of its contents appears in earlier volumes of the series *Science and Civilisation in China*.[97] In the context of ceramics, a section entitled 'Jar Painting' described the waterproofing of earthenware storage jars, a type of vessel essential for domestic comfort.

More than 1,000 years later, Sung Ying-Hsing's 宋應星 *Thien Kung Khai Wu* (The Exploitation of the Works of Nature, +1637) was compiled at a time in the late Ming dynasty when several major works on natural history, agriculture and technology were being assembled.[98] It was unusual both for its originality of form[99] and its

[95] For a resumé of ceramic literature see Wang Chhing-Cheng (1982), pp. 185–6.

[96] Needham & Wang (1954), pp. 42–54, 73–9; Beasley & Pulleyblank (1961); Wilkinson (1973); Bray (1984), pp. 47–85; Daniels (1996), pp. 45–51.

[97] Bray (1984), pp. 55–9; H.T. Huang (2000), pp. 123–4, table 12.

[98] For example, *Pen Tshao Kang Mu* (Great Pharmacopoeia, +1596); *Wu Pei Chih* (Records of War Preparations, +1628); *Nung Cheng Chhüan Shu* (Complete Treatise on Agriculture, +1639). See Bodde (1991), p. 269n.

[99] Bray (1984), p. 76.

choice of subject-matters. The originality may perhaps be explained by Sung's conventionally apologetic remarks in the preface, where he laments his lack of funds and opportunity to discuss the text with other scholars:[100]

> The result, therefore, is that the book has been written entirely out of what I have carried in my own head, based on inadequate observations and scanty knowledge.
>
> 只好任憑自己一點粗淺見聞, 記在心裏, 寫在紙上, 這就難免有不當之處.

The contents were divided into three sections, dealing first with the important businesses of agriculture, and then with a range of products including ceramics, castings, paper, weapons, pearls and gems. The section on ceramics provides a thoughtful review that encompasses firstly building materials, secondly domestic storage vessels and only lastly fine white porcelain.

Sung Ying-Hsing's 'inadequate observations' were discerning, for a variety of ceramic manufactures is described in terse prose by a man who possibly witnessed many of the processes. The description of the introduction of water to a kiln at the end of the firing kiln for bricks, for example, encompassed a model that had been current in north China for more than 2,000 years. Likewise the kiln for firing large water jars is recognisably a linked chamber climbing kiln, a type of 'dragon' kiln widely used in south and south-east China.[101] The section devoted to high-fired whiteware concentrated most attention on the products of Ching-te-chen, describing porcelain-making from the collection and processing of china stone, through forming, glazing, painting and firing. Without resort to connoisseurial judgement or literary quotation, Sung Ying-Hsing also mentions products from Hopei, Kansu 甘肅, Shansi, Honan, Anhui 安徽 and Fukien 福建 provinces. His approach is made clear by his comment on Te-hua 德化 'Blanc de Chine' porcelain from Fukien, as comprising delicate figurines with no practical function.[102]

Ceramic materials also had a place in Chinese pharmacology. The literature is vast, and here it may suffice to refer to *Cheng Lei Pen Tshao* (Reorganised Pharmacopoeia, +1108), and the classic *Pen Tshao Kang Mu* (+1596). *Cheng Lei Pen Tshao* describes 'porcelain earth' (*pai-e* 白堊) as being used for medicine and other activities. Quoting the works of Thao Yin-Chü, 陶隱居 (+456–536), it described the employment of porcelain clay (kaolin) in painting pictures, though ceramics were not mentioned.[103] Citing *Thang Pen Tshao* (Pharmacopoeia of the Thang Dynasty, +660) it noted the infrequent use of porcelain clay (including that from Ting-chou 定州) for medicine, its continued efficacy for painting, and its recent introduction in the manufacture of white porcelain.[104] This chronology accords with archaeological evidence that has established the earliest manufacture of white porcelain in north China in the later +6th century (see pp. 146–63).

[100] *Thien Kung Khai Wu* ('Hsü'), p. 1b. Sun & Sun (1966), p. xiv.
[101] *Thien Kung Khai Wu*, ch. 7, pp. 3a, 5a–b. See Part 3, pp. 347–59 of this volume.
[102] *Thien Kung Khai Wu*, ch. 7, pp. 5b–8b.
[103] *Liang Shu* ('*Lieh Chüan*'), ch. 51, p. 12, where Thao's name appears as Thao Hung-Ching 陶宏景. Porcelain clay was used in preparing backgrounds for overpainting, both in mural painting and on sculpture.
[104] *Cheng Lei Pen Tshao*, ch. 5, pp. 22, 32. Cf. Hirth (1888), pp. 3–4.

From *Pen Tshao Kang Mu* we learn that fine, crushed, white porcelain from Ting-chou was efficacious for nose-bleeds, while white porcelain from the same area was employed for pain in passing water. For burns and similar injuries powdered sherds from green porcelain bowls were recommended, and porcelain from Ching-te-chen was used specifically. Square bricks of *pai-ê* were good for washing clothes, as well as for making porcelain. One form of the mineral asbolite (*wu-ming-i* 無名異) was used to decorate porcelain.[105] Another form of the ore, rich in manganese, with some iron, was also used as a medicine for curing wounds. *Pen Tshao Kang Mu* records the collection of pellets of *wu-ming-i* in Kweichou province 貴州省 for this purpose.[106]

GAZETTEERS

Gazetteers (in general *fang-chih* 方志, titled *ta-chih* 大志, *thung-chih* 通志, *fu-chih* 府志 or *hsien-chih* 縣志) were compiled from early times, though relatively few are available for the pre-Ming period.[107] Ming and Chhing dynasty gazetteers are quite numerous, and the *genre* continued into the +20th century.[108] They comprise encyclopaedic accounts of the geography, history, economy, religion, local customs, products etc. of specific administrative divisions of the empire, in a continuum from those of imperial scope down through province and prefecture to district level. Good examples contain details of surrounding scenery, official personnel, local industry, ancient remains or 'miscellanea', all of which can encapsulate information on local ceramic manufacture. The records were often rewritten, updated or extensively revised. *Chiangsi Thung Chih* (Geography and Topography of Chiangsi Province), for example, was begun in the Ming Chia-Ching reign period, and revised five times during the Chhing, while *Shao-hsing Fu Chih* (Local Gazetteer of Shao-hsing) was begun in the Khang-Hsi reign period and then actually lost, needing to be rewritten during the Chhien-Lung reign period.

Gazetteers vary in content, and in quality, and often contain material appropriated from elsewhere. It is perhaps important to note that due to the derivative and accumulative nature of Chinese compilation of historical sources, it is often the latest edition of gazetteers that prove to be the most comprehensive.[109] Antecedents can also repeat information at different levels of detail. An example of this is provided by three gazetteers that document activities at Ching-te-chen 景德鎮. The city of Ching-te-chen is in Fu-liang county 浮梁縣, which is in the prefecture of Jao

[105] Asbolite is one form of cobalt ore. It is discussed in more detail with regard to its use in cobalt-blue glazes and in- and underglaze decoration, in Parts 5 and 6 of this book.

[106] *Pen Tshao Kang Mu*, ch. 7, p. 1, ch. 9, p. 561; Anon. (1978a), p. 36; Chen *et al.* (1995), pp. 291–4–3.

[107] Chang Kuo-Kan (1962) contains details of more than 2,000 works complied from the Chhin to Yuan dynasties; but nearly all of them are no longer extant.

[108] There are about 900 Ming dynasty *fang-chih* extant, about 5,000 Chhing dynasty, and 650 of Republican period date. Wilkinson (1973), p. 116.

[109] It is not the purpose of this volume to discuss textual comparisons: one example will suffice to show the diversity of information provided by different levels, and different editions, of gazetteers. The +1880–81 edition of *Chiangsi Thung Chih* actually provides the longest and most densely annotated passage on pre-Yuan dynasty ceramics at Ching-te-chen. It has more information than that supplied either by the +1851 abridged edition of *Fu-liang Thao Chen Chih*, or the +1872 edition of *Jao-chou Fu Chih*.

饒州, within Chiangsi province. The gazetteer of the local county (*Fu-liang Hsien Chih*) thus contained material that was abridged and summarised for the prefectural gazetteer (*Jao-chou Fu Chih*) and the provincial gazetteer (*Chiangsi Thung Chih*). If compiled by a competent scholar, county gazetteers provided fruitful information about industries in their own, small area. This was recognised in the writings of early Western scholars such as Père d'Entrecolles (+1712, +1722) and Bushell (+1896), who both studied *Fu-liang Hsien Chih* for detailed information about the local ceramic industry.

Sorting out editions of gazetteers and deciding where material originated can be problematic. A case in point is a fourth Chiangsi gazetteer, *Chiangsi Sheng Ta Chih* (The Great Gazetteer of Chiangsi Province). Compiled in +1556 by Wang Tsung-Mu 王宗沐, only three of its original seven *chüan* 卷 survived. It was reprinted with additional material in +1597, and it is this edition that has generally been consulted.[110] The most important addition to the second edition was *chüan* 7 '*Thao Shu*' (陶書, Book on Ceramics). This was based on a no-longer extant monograph called *Thao Cheng Lu* (陶政錄, Record of Pottery Management) by Chhen Hsüeh-Chhien 陳學乾, Assistant Prefect of Jao-chou during the Lung-Chhing reign period. *Thao Shu* comprised an exhaustive account of porcelain production in the +16th century, presented under 24 headings:

Preface
Position and construction of pottery factories
Notes on the imperial factory
Official buildings
Raw materials: clays
Precise clay requirements
Labour
Official supervision
Cobalt-blue
Vessels: quantities, qualities and cost estimates
Kiln manufacture
Management reports
Corvée labour
Labour requirements
Production processes
Fuel
Colours
Colour requirements
Vessel requirements and costs
Transport
Packing
Supply of imperial wares
Costs for materials
Annotated comments

[110] For example, Medley (1966), p. 327; Medley (1993), pp. 71–2; Daniels (1996), p. 50.

Large portions of *Chiangsi Sheng Ta Chih* were in turn appropriated for inclusion in the +18th- and +19th-century additions of *Jao-chou Fu Chih* and *Chiangsi Thung Chih*.

The compilations described thus far deal mainly with Ching-te-chen in Chiangsi province. Gazetteers for other provinces and areas encompass information on kilns elsewhere, and selections from them have been included elsewhere in this volume.

Literature Concerned Specifically with Ching-te-chen

A large proportion of the literature concerned with ceramic manufacture deals with production at China's most illustrious 'porcelain city', Ching-te-chen in Chiangsi province. Connoisseurial and scholarly monographs that touch on the subject sometimes exist as independent works. One such example is Wang Shih-Mao's 王世懋 *Khuei Thien Wai Chheng* (Annals Written in Retirement) of +1589, that includes a section on porcelain written when Wang was an official in Chiangsi province in +1576–81.[111] Other studies have only been transmitted by inclusion in gazetteers. Two such are Chiang Chhi's 蔣祈 *Thao Chi* (Ceramic Memoir) of either +1214–34 or +1322–25 (scholars in China disagree about the date[112]) and Kuo Tzu-Chang's 郭子章 *Yü-chang Ta Shih Chi* (The Important Events of Yü-chang) of the early +17th century.

The study of Chinese ceramics has caused acerbic discourse from early times to the present day. In his work *Thao Chi*, one of Chiang Chhi's stated aims was to comment on the views of another scholar Hung Mai 洪邁, who in a book called *Jung Chai Sui Pi* (Notes from Jung Chai Studio, +1880–87) had included a short section on 'Ceramics from Fu-liang'.[113] Chiang reflected on Hung's citation of only *two* incorrupt local officials who did not abuse their positions to profit from private trading in ceramics – why were incorrupt officials so hard to find? Chiang's morose account also gave details of the declining state of ceramic production at Ching-te-chen owing to corrupt officials, bad management, high taxation, lack of fuel owing to earlier over-exploitation of resources and the disquiet felt by nine out of ten local businessmen. However, other passages contain useful and precise information

[111] Goodrich & Fang (1976), pp. 1406–8; Watt (1979), p. 70.

[112] The facts are reviewed in Liu Hsin-Yüan (1981); Liu Hsin-Yüan (1983a); Liu Hsin-Yüan (1983b); Hsiung Liao (1983); Feng Yunlong (1995), p. 295. Briefly, Chiang Chhi was known as an official familiar with kilns at Ching-te-chen, possibly active in the period +1214–34. No early manuscript versions of his *Thao Chi* survive. It was first mentioned in the +1682 edition of *Fu-liang Hsien Chih*, the earliest extant edition in China. However, the +1682 version did not include the section on 'products' which is where *Thao Chi* was cited in the +1742 edition of *Fu-liang Hsien Chih*. In the +1742 version 'Chiang Chhi's Yuan Dynasty Summary of Ceramics' was mentioned, and as there were no substantial editorial changes between +1682 and +1742, it is conjectured that a Yuan attribution for *Thao Chi* goes back some way. Lan Phu in his *Ching-te-chen Thao Lu* (+1815) cites the work as being Yuan dynasty. The authors of this volume accept a Southern Sung date for the work.

[113] *Jung Chai Sui Pi*, ch. 4, p. 13.

about kiln ownership, stacking and firing, sources and uses of local clay deposits, and quality-control.[114]

Passages concerning porcelain production from *Yü-chang Ta Shih Chi* are quoted in the gazetteers *Chiangsi Thung Chih*[115] and *Jao-chou Fu Chih*.[116] They contain the type of information familiar from historical records about manufacturing quotas, the rise and fall of supervising officials, and failures in production. One of the more engaging entries about transmutation of glazes and forms in firing concerns porcelain screens ordered by the court of the Wan-Li emperor. They failed in the kiln, and during +1588–9 were transformed first into 6 × 1 foot bed-boards, then cut down to 3 foot and finally (these enterprising solutions having been condemned by prefectural and county officials of Jao-chou) had to be destroyed.[117]

A longer and more descriptive monograph was Chu Yen's 朱琰 *Thao Shuo* (Description of Ceramic, +1774). Chu Yen was a native of Chekiang province, a scholar and connoisseur who wrote numerous books on philology, music and poetry. Sadly, some works were never printed, while others have not survived. We know about Chu's output from a relative called Huang Hsi-Fan 黃錫蕃, who in +1787 added a respectful fourth preface to a new addition of *Thao Shuo*. From the third preface (+1774) by Pao Thing-Po 鮑廷博, we learn that in +1767 Chu Yen was appointed by Chiangsi province Grand Palace Coordinator Wu 大中丞吳, to a post in his personal office.[118] Chu Yen appears to have been employed there up to the time when *Thao Shuo* was published. During these years he travelled around Ching-te-chen making personal inspection of both imperial and private kilns. This direct experience gave the book authority and contributed to its immediate success. Indeed, it has acted as a reference source for scholars down the centuries.[119]

Thao Shuo is arranged in six books, each further subdivided into short subject-sections. Table 1 gives an outline of the contents.

Thao Shuo is a work of straightforward description, including both information derived from earlier sources, and observations from personal investigation. It is augmented by information provided by another expert directly involved in manufacture, namely Thang Ying 唐英, Assistant and later Superintendent of the imperial factory between +1728 and +1756[120] (see below). The discussion of a series of illustrations of ceramic manufacture in Book I is taken directly from the *Thao Yeh Thu Pien Tzhu* 陶冶圖編次 (Illustrated Explanation of Ceramic Production), compiled by Thang for the Chhien-Lung emperor in the fourth month of +1743.[121]

[114] Chiang's text is reproduced and annotated in Pai Khun (1981) and Yen Shih-Lin (1981). Portions of it are translated by Bushell (1896), pp. 99–102.
[115] *Chiangsi Thung Chih* (1880 edn), ch. 93, pp. 7a–b.
[116] *Jao-chou Fu Chih* (1872 edn), ch. 3:3, p. 62.
[117] *Jao-chou Fu Chih* (1872 edn), ch. 3:3, p. 2a; *Chiangsi Thung Chih* (1880 edn), ch. 91, p. 7a.
[118] *Thao Shuo* (*Hsü*), pp. 2a–b. Hucker (1985), p. 464.
[119] See Bushell (1910), pp. vii–viii. Stephen Bushell's translation of +1910, though it can be corrected in several places, gives the non-reader of Chinese a good understanding of the work.
[120] Kerr (1986), p. 19.
[121] Fu Chen-Lun & Chhen Li (1982), p. 38, pls. 1–5.

Table 1 *Contents of the* Thao Shuo

Book no.	Contents
I	Discussion of modern ware (Jao-chou ware; discussion of the Thang Ying series illustrating ceramic manufacture)
II	Discussion of ancient ware (origins, investigation of ancient kilns)
III	Discussion of Ming dynasty ware (Jao-chou ware, methods of manufacture: materials and pigments, imperial factory, painters and designs, sagger-making, kiln-firing)
IV	Discussion of different wares, part 1 (Thang and Yü wares, wares of the Chou, Han, Wei, Chin, Southern and Northern and Sui dynasties)
V	Discussion of different wares, part 2 (wares of the Thang, Five Dynasties, Sung and Yuan dynasties)
VI	Discussion of different wares, part 3 (wares of the Ming dynasty)

Thang Ying died in +1756, so Chu Yen almost certainly did not meet him. However, Thang's influence at the imperial factory continued to be strongly felt during the second half of the +18th century, and the fact that Chu incorporated his experienced (and almost contemporary) descriptions in the text of *Thao Shuo* says much for the standing of both men.

The chapters on pre-Chhing dynasty wares inevitably rely on selected quotes from classical and historical sources. The extracts are well chosen and informative, however, and are interspersed with the author's own observations and conclusions. For example, in a section on Chhheng-Hua period porcelain Chu Yen compares the views expressed in the +17th-century *Po Wu Yao Lan* (A General Survey of Subjects of Art) with those of two other, dissenting, Ming and early Chhing sources, about the relative merits of wares from different reign periods. He decides:[122]

> In summation, Ming dynasty Hsüan-Te and Chhheng-Hua wares are unsurpassed, moreover each period in turn had its own excellent features, and thus the words of *Po Wu Yao Lan* are confirmed.

In terms of pottery manufacture, Book I plus the section on methods of manufacture in Book III are most useful, though remarks on raw materials and design occur

[122] *Thao Shuo*, ch. 3, p. 3b.

throughout the work. The description of sagger-making during the Ming dynasty gives a flavour of Chu's straightforward style:[123]

> The manufacture of saggers employed yellow clay and sand mixed together, and used as needed for large or small saggers. The sagger kiln, excluding the huge saggers needed for dragon cisterns, could fire 70 or 80 items (at a time). It was reckoned that each firing used 55 loads of firewood. Some containers could be used only once, while others were used again before being disposed of.

We have already mentioned the compelling *oeuvre* of the great Thang Ying (+1682 – 1756), Superintendent of the imperial factory at Ching-te-chen. Unlike literati authors, Thang was writing about pottery manufacture from a position of direct, commercial experience. He did not come from a Han Chinese scholarly background, for his great-grandfather was a bondservant captain (*pao-i chhi-ku-jen* 包衣旗鼓人), and Thang himself was a Chinese bannerman who served at the court of the Khang-Hsi emperor for more than twenty years before taking up his duties at Ching-te-chen.[124] During his long and arduous service there, Thang found time to write several books.[125] Many consisted of miscellaneous outpourings on a wide range of subjects that interested him. Thus *Thao Jen Hsin Yü* 陶人心語 ('Words from the Heart of a Potter', initially completed in +1740) contained over 1,000 pieces of poetry, essays and comments on calligraphy, history, moral teachings and personal duties. *Ku Po Thang Chhuan Chhi* 古柏堂傳奇 (Tales from the Hall of the Ancient Cedar) was a collection of seventeen moralistic operas, while *Wen Chhi Tien Chu* 問奇典注 (Curiosity Explained) was a dictionary of phrases with over 1,000 entries. Of greatest pertinence to our study are his miscellaneous writings (*Tsa Chu* 雜著), a collection of more than 140 pieces of text concerning Thang's day-to-day work at the imperial factory and including 43 reports to the Chhien-Lung emperor dating between +1736 and +1756. Here also are found four essays on ceramic management, *Thao Wu Hsü Lüeh* 陶務敘略 (A Brief Account of Ceramic Affairs) and *Thao Chheng Chi Shih* 陶成記事 (Memorial on Ceramic Production) both of +1735; *Tzhu Wu Shih I Shih Yü Kao Hsü* 瓷務事宜示諭稿序 (Report on the Porcelain Business) of +1736; plus *Thao Yeh Thu Pien Tzhu*, mentioned earlier, completed in +1743, an important and comprehensive treatise on pottery production comprising twenty

[123] *Ibid.*, p. 8b.

[124] Hummel (1943), p. 442. From the age of sixteen, Thang Ying was a page in the *Yang-hsin Tien* 養心殿, an agency of the Imperial Household Department (*Nei-wu Fu* 內務府) staffed by eunuchs and bondservants, that produced things needed in the ordinary service of the Emperor, cf. Hucker (1985), p. 576. Here he learnt various accomplishments such as painting, design production, poetry and play-writing. In +1723 Thang was promoted as Vice-Director of the Imperial Household Department to supervise painters at the palace. In +1728, under imperial orders, he travelled to Ching-te-chen to assist the Superintendent of the imperial factory Nien Hsi-Yao 年希堯. At the end of +1735 Nien was removed from his post on corruption charges and Thang took over as Superintendent. He served in this post, with brief interruptions for other duties, until the year of his death (+1756). See Bushell (1896), pp. 206–10; Fu Chen-Lun & Chhen Li (1982); Kerr (1986), pp. 19–20; Chang Fa-Ying & Tiao Yün-Chan (1991), vol. 1. A full account of Thang Ying's career and a list of the pots he himself commissioned and decorated is provided by Peter Y. K. Lam (2000).

[125] Thang's voluminous writings have been gathered together from the various national libraries of China and arranged into two volumes by Chang Fa-Ying & Tiao Yün-Chan (1991). A useful concordance is provided by Fu Chen-Lun & Chhen Li (1982), pp. 19–54, 55–66.

commentaries accompanying illustrations.[126] Thang's writings on ceramics provide information for the section on Ching-te-chen on pp. 184–213 of this volume. His reputation lived on in folk mythology, and in the popular songs composed by the potters of Ching-te-chen to accompany their work. A flavour of those rhythmic chants is provided by this stanza, captured in written form in the +19th century by Kung Shih 龔軾:[127]

> The mountains' stony bones give out clay
> Water-powered trip hammers pound it in mountain streams
> If the workshop boss says it's not OK
> It won't get parcelled up and freely shipped away.
>
> 在山石骨出山泥
> 水碓舂成自上溪
> 要是高莊稱好不
> 不船連載任分攜

Another book about the 'porcelain city' was *Ching-te-chen Thao Lu* (An Account of Ceramic Production at Ching-te-chen), written by Lan Phu 藍浦 during the Chhien-Lung reign period and completed by Cheng Thing-Kuei 鄭廷桂 in +1815. It has a preface by the local magistrate of Fu-liang county, who mentions that Lan Phu was born and bred in the area, and recorded his impressions of the porcelain industry from observation. Because Lan Phu's initial account only survived in draft form, and was completed by another man, we cannot know that it takes the form he initially envisaged. The work is in ten books, and covers the pottery business in some detail. The first book, added in by Cheng Thing-Kuei, touches on the history of the town and the imperial factory, once again with material taken from Thang Ying's celebrated illustrations of manufacture. Books two to four cover contemporary (i.e. +18th-century) products and manufacture; book five past products; book six reproductions of past products made at Ching-te-chen; book seven information about kilns elsewhere; and books eight to ten a compilation of literary sources. It thus adopts the rather haphazard form common to many Chinese monographs, but nevertheless includes helpful material, and has been widely quoted by both Chinese and Western scholars in their work.[128]

THE LITERATURE OF CONNOISSEURSHIP

In the pre-Thang dynasty era, sources commented on the ritual or functional capability of items, but it was not until the +8th century that comments on aesthetic values started to appear. Appreciation of ceramics was linked with the rise of tea

[126] This is the work incorporated into Chu Yen's *Thao Shuo*, ch. 1, pp. 2a–12b. A translation is provided by Bushell (1910), pp. 7–30. The paintings were originally kept in the Forbidden City, but left China at some point. They were believed to have been taken to Japan and destroyed in World War II. However, they resurfaced at a Christie's auction in Hong Kong in +1996 and are now in Taiwan, see Peter Y. K. Lam (2000), p. 78.

[127] Poem no. 3 in the chapter 'Materials' in *Ching-te-chen Thao Kŏ* (1824), see Yang Ching-Jung (1994), p. 34.

[128] Translations are available: incomplete version Julien (1856), also Sayer (1951).

culture, and with the concurrent manufacture of high-quality green and white wares. The two wares mentioned most frequently in Thang dynasty literature were Yüeh 越 greenware from Chekiang province, and Hsing 邢 white porcelain from Hopei province. The relationship between scholars and producers was a mutually influential one, for connoisseurs both promoted refinement and increased sales of favoured types. Enhancement of existing products was achieved through improvements in technology: thinner throwing and moulding, careful composition of glazes, and kiln control. In the case of Hsing ware, patronage from influential circles in society contributed to the success of a totally new product, true white porcelain.

During the Sung dynasty an expansion in kiln activity across China occurred, resulting in a greatly extended number and range of ceramic wares. In part, this can be explained by rapid rises in population and consequent demand for daily-use utensils, in part by an expanding export trade in ceramics and in part by a marked degree of product specialisation. Thus, for example, one category of pots was made to supply the needs of brewers and distillers, giving rise to a range of wares for storing and consuming alcohol.[129] A second category was selected for use at the imperial court.

A third category of Sung pots was that appropriated by literati, for collecting and use. Appreciation of the antiquity, rarity and consequent desirability of certain categories of objects gave rise to connoisseurship and collecting among the upper echelons of society. Art collecting as a status activity was given impetus by imperial example; emperor Hui Tsung 徽宗 (r. +1101–25) is said to have built up a collection of 10,000 pieces. Collectors were inspired by paintings, bronzes and jades. Antiquities dug up from ancient sites (either by accident or design) were also treasured. The development of printing enabled the compilation and circulation of books devoted to particular kinds of things. The contents of these handbooks of gracious living consisted of what has been termed 'composition through compilation',[130] a practice of free borrowing from one text to another in which whole passages were transcribed. Quotations were then amplified or modified, and interspersed with the writer's own discussion.[131] Such texts, first circulated in the Southern Sung dynasty, reached a peak of popularity in the Ming period.

[129] Cf. Mino (1980), pp. 160–1, 188–9, 194–5.

[130] Bodde (1991), p. 85.

[131] Most popular were catalogues of bronzes and inscriptions on bronzes; some of these works were illustrated by line drawings of vessels, and most included rubbings of inscriptions. Foremost extant works comprise: *Khao Ku Thu* (Research on Archaeology with Drawings) of +1092; *Chhung Hsiu Hsüan-Ho Po Ku Thu Lu* (Drawings and Lists of All Antiquities Known at the Hsüan-He Reign Period, Revised Edition) of +1123; *Chin Shih Lu* (Collection of Texts on Bronze and Stone) of +1119–25; *Hsiao Thang Chi Ku Lu* (Records of the Collection of Antiques of the Whistling Studio) of *c.*+1123; *Li Tai Chung Ting I Chhi Khuan Chih Fa Thieh* (Copies of Inside and Outside Inscriptions on Bells, Cups and Vessels Throughout the History of China) of +1144. These volumes were reissued in multiple editions during the Ming and Chhing dynasties. See Kerr (1990), pp. 13–18.

More pertinent to ceramics were unillustrated monographs whose aim was to act as guides for the scholar of elegant taste. This genre was first recognised among Western scholars by van Gulik (1958). A discussion of Ming dynasty literature forms the core of a pioneering work by Clunas (1991).

It could be argued that it was not the intention of this category of literature to offer information on ceramic technology, and that it has little use in the context of our present study. By way of reply, one may consider firstly, the genre's strong effect on Chinese scholarship down to the present day and secondly, the pressure exerted on ceramic manufactories by consumer demand. Changes in fashion were reflected in changing orders for ceramics. For example, by the late Ming dynasty educated taste had established a hierarchy that privileged plain, monochrome wares of the Sung dynasty. A lack of sufficient Sung ceramics caused many kilns to imitate Sung bodies and glazes, some of which circulated as genuine early wares.[132] By the +18th century, the Yung-Cheng and Chhien-Lung emperors were investing considerable resources at the imperial factory to reproduce complex Sung glaze effects.[133] Imperial lists indicate how important successful imitations were in the annual order (see pp. 206–7).

Robbert Hans Van Gulik has identified the first manual of taste as being *Tung Thien Chhing Lu Chi* (Records of the Pure Registers of the Cavern Heaven, also translated as Conspectus of Criticism of Antiques), written by Chao Hsi-Ku 趙希鵠 in the years around +1230.[134] Chao (+1170–1242), a member of the Sung imperial family, composed a text covering ten categories of both antique and contemporary items.[135] Ceramics did not feature as a distinct category, though Chhang-sha Thung-kuan ware 長沙銅官窯 was mentioned briefly in the context of water vessels for the desk.[136] A work of more straightforward description is Thao Tsung-I's 陶宗儀 *(Nan Tshun) Chho Keng Lu* (Record (from South Village) While the Plough is Resting, +1366), which although published in the Yuan dynasty incorporates much that could be considered Southern Sung in content.[137] A section on ceramics mentions *mi-se* Yüeh ware 秘色越窯,[138] Ting ware 定窯 with unglazed rim, Ju ware 汝窯, Lung-chhüan ware 龍泉窯 and Kuan ware 官窯.

Another manual concerning itself with ceramics was *Ko Ku Yao Lun* (Essential Criteria of Antiquities), written by Tshao Chao 曹昭 during the early Ming dynasty, in +1388.[139] The wares discussed were 'ancient' ones (*ku* 古), in other words the author was mainly concerned with an evaluation of things made in former

[132] Clunas (1989), pp. 51–2; Clunas (1991), pp. 101–3.

[133] Watt (1987), p. 8. For a discussion of Chün ware glazes and their imitation in the Chhing dynasty, see Kerr (1993).

[134] Van Gulik (1958), p. 51.

[135] They comprised: antique *chhin* 琴 zithers, antique inkstones, antique bronze vessels, curious rocks, table screens, brush rests, water vessels for the table, antique manuscripts and calligraphy, antique and modern rubbings of stone inscriptions, antique paintings. See Clunas (1991), p. 9.

[136] *Tung Thien Chhing Lu Chi*, p. 17a.

[137] Franke (1961), p. 128. This stricture is especially relevant to passages on ceramics contained in ch. 29 (*Tao Chhi* 窯器 'kiln ware'), that quote directly from Yeh Chih's 葉寘 Southern Sung text *Than Chai Pi Heng*. See also p. 259 of this volume.

[138] The passage states that *mi-se* ware was made by the Chhien clan 錢氏, and fired at Yüeh-chou, for tribute wares and not for the use of ordinary people or officials. A slightly differently worded version of this information also appears in the late Southern Sung work *Fu Hsüan Tsa Lu*, which in turn is cited in the gazetteers *Yü-yao Hsien Chih* (1899) and the revised *Chekiang Thung Chih* (1899).

[139] The work is accessible to English readers in the translation by David (1971), which also contains critical and bibliographical context and a facsimile of the Chinese text.

times, occasionally comparing them with contemporary products.[140] The section on ceramics listed sixteen wares, fourteen from named kiln areas, and its format and content set a standard that influenced later Ming and Chhing dynasty handbooks.

The world of the late Ming literatus has been extensively researched in recent years.[141] At that period economic, political and social factors combined to provide an environment in which appreciation of arts and literature could become an end in itself. A gulf existed between *nouveau riche* patrons of mercantile background, with money to buy objects but no skills to write about them, and educated literati. The latter congregated in cities, many in the south-eastern Chiang-nan 江南 region, their social environment bounded by self-regulating rules of style and taste. Their aesthetic canon was enshrined in a welter of publications, whose concerns mirrored an established hierarchy of taste. This hierarchy encompassed both intellectual pursuits and categories of collecting. Items collected were still termed antiquities (*ku* 古), though by the late Ming this could stand for all works of art, both old and new. At the top stood poetry, calligraphy, painting and seal-carving. These superior activities were practised by educated gentlemen, who also amassed the work of others (both antique and modern). In addition to paintings and calligraphies, the discerning collector developed an interest in every kind of fine object, including jade, carvings and ceramics. An oft-quoted list of collectable objects[142] by the eminent literatus/connoisseur Li Jih-Hua 李日華 (+1565–1635), ranked 23 things in order of preference. At number 23 stood 'shiny white fine porcelain and *mi-se* ceramics, old and new'. The decoration of the 'fine white porcelain' would have been important, both as regarded subject and style. In the +17th century, it was said that the elite wanted the artistry of *wu-tshai* 五彩 ('five-coloured' polychrome), while the general public made do with cheap undecorated ware.[143]

The admiration of scholars like Li Jih-Hua for ceramics did not, in the main, extend to humble artisans who manufactured them. Although Li's diaries and writings reveal that he was knowledgeable about ceramics, and knew some potters personally, these contacts were limited to literati potters whose work could be extolled (and improved) by scholarly patrons. The sweaty toil of factory potters in Chekiang or Chiangsi was beyond the reach of the fashionable mind. Disdain for the artisan assumed even greater proportions at court, where reactionary officials petitioned for revocation of imperial orders bestowing official rank on craftsmen of exceptional merit.[144] The disapprobation of artisans had deep roots in China, as we have remarked on the section about potters' status in early China (pp. 16–19).

However, the late Ming literati world also produced and supported some interesting men who turned their hand to pottery. One was the talented poet, potter and

[140] For a discussion of the total contents of *Ko Ku Yao Lun* see Clunas (1991), pp. 11–13. One should also take note of that author's caution against unconsidered use of parts of texts, without appraising their integrity.

[141] Li Chu-Tsing & Watt (1987); Clunas (1991). Bibliographical material in their works provides copious pointers to further research.

[142] Li Chu-Tsing & Watt (1987), pp. 15–16; Clunas (1991), pp. 104–5.

[143] *Fu-liang Hsien Chih* (1682 edn), ch. 4, p. 46a.

[144] Watt (1987), pp. 8–9.



Fig. 5 +18th-century yellow-glazed table screen with an imitation seal-mark *Hu-Yin Tao-Jen*

painter Hao Shih-Chiu 昊十九 (a.k.a. Hu-Yin Lao-Jen 壺隱老人, the 'Hidden Old Man of the [Tea] Pot') a native of Fu-liang who lived during the Wan-Li reign period. Noted in literature, his identification was confirmed in +1973 when an inscribed porcelain tablet mentioning his name was excavated at Tu-chhang 都昌.[145] The name was used in an alliterative manner on later ceramics, for example a fine yellow-glazed table screen in the Percival David Foundation of Chinese Art with an imitation seal-mark *Hu-Yin Tao-Jen* 壺隱道人 (the 'Taoist of the [Tea] Pot').[146]

[145] *Ching-te-chen Thao Lu*, ch. 5, p. 6a-b; Fu Chen-Lun (1993a), p. 36.

[146] Other potters also adopted the style name *Hu-Yin* 壺隱, including the I-hsing potter Chhen Ming-Yüan 陳鳴遠, see Ming Wilson (1998) who publishes the table screen on pp. 112–13, no. 46.

Another was Chou Tan-Chhüan 周丹泉, a redoubtable potter, artisan in wood, lapidary and lacquerer, antique faker and dealer, and confidence trickster, who was active in the Lung-Chhing and Wan-Li reign periods. Ellen Johnston Laing has identified him as being the same man as the painter Chou Shih-Chhen 周時臣, and has assembled information on his remarkable life.[147] As a potter, Chou's main claim to fame was as an imitator of Sung dynasty Ting ware censers,[148] that he had made in Ching-te-chen and then proceeded to sell to gullible clients in other regions.

Ceramic appreciation did not cease in the Chhing dynasty, as we have seen from the work of men like Chu Yen and Lan Phu, mentioned above. A work dating earlier than their monographs was the anonymous *Nan Yao Pi Chi* (Notes on Southern Kilns), probably published in the Yung-Cheng reign period.[149] A short work, it is a curious mixture of recycled remarks on famous wares (Ju ware, Kuan ware etc.) and information on practical aspects of ceramic production at Ching-te-chen. These latter sections contain useful remarks on body and glaze preparation, forming and firing.[150]

In the late Chhing and Republican periods there was an outpouring of connoisseurial writing, based on traditional scholarship and stimulated by the thriving international antiques market in China's major cities. Two notable works from that time are Chhen Liu's 陳瀏 *Thao Ya* (Pottery Refinements, +1910) and Hsü Chih-Heng's 許之衡 *Yin Liu Chai Shuo Tzhu* (Talks on Porcelain from the Yin Liu Studio). Chhen Liu concealed his identity under a pen-name for the publication of *Thao Ya*, calling himself 'The Old Man of the Quiet Garden' 寂園叟. Chhen was born in Chiangsu province 江蘇省 but worked for more than twenty years as an official in Peking 北京, spending his spare time collecting ceramics and lecturing on them. He was in the capital at a time when great treasures were coming on to the market from the imperial collections, sold off both legally and illegally to furnish funds for a regime bankrupted by indemnities for the Sino-Japanese war of +1894 and the Boxer Rebellion of +1900. His monograph was first published in +1906 under the title *Tzhu Hsüeh* 瓷學 (Study of Porcelain), but was subsequently revised and published in +1910 as *Thao Ya*.[151] It was reprinted in the +1930s, and in spite of its dilettante nature has been regarded as a valuable reference work by Chinese scholars ever since.[152] Chhen took as his starting point the reigning (Chhing) dynasty,

[147] Laing (1975), who also summarises in her footnotes details of published information on Chou in both Chinese and English. Chou's ceramic prowess was mentioned by Julien (1856), p. 103; Hetherington (1922), pp. 94–5; Hobson (1923), p. 158; Brankston (1938), p. 65; Honey (1945), p. 92; Jenyns (1953), p. 128.

[148] *Ching-te-chen Thao Lu*, ch. 5, p. 6a.

[149] Cf. Wang Chhing-Cheng (1982), p. 186.

[150] *Nan Yao Pi Chi*, pp. 7a/323–11b/332.

[151] Sayer (1959), pp. vii–viii. Sayer accomplished a useful translation of the text, with explanatory introduction.

[152] It is often cited as a successor to *Thao Shuo* and *Ching-te-chen Thao Lu*. Yeh Che-Min 葉喆民 , an eminent contemporary scholar and teacher, expresses this view in an unpublished paper *Chung-Kuo Ku Thao-Tzhu Wen-Hsien Lüeh-Than* 中國古陶瓷文獻略談 (A Brief Examination of Chinese Literature on Traditional Ceramics), pp. 84–5, a copy of which he presented to one of the authors (RK) in +1998. Chhen Liu was not so kind to his illustrious predecessors. He praised *Thao Shuo*, but called *Ching-te-chen Thao Lu*: 'completely obscure and full of mistakes'. Ch. 1, p. 34b; Sayer (1959), p. 56.

and paid special emphasis to the three reign periods of Khang-Hsi, Yung-Cheng and Chhien-Lung. His was a connoisseurial discussion, and it emphasised decline in standards in the +19th century. This view of Chinese ceramics – a peak in the early +18th century and a trough in the +19th – has been a view adopted by many Chinese and Western writers in the +20th century. The book is a jumbled mass of repetitive information without chronology and sequence. However, its reliance on personal evaluation of real pots, together with advice on reproductions and fakes, was precisely the sort of information that collectors thirsted to obtain.

Hsü Chih-Heng was a scholar and collector from Canton, who died in +1925. As a young man, he attended Meiji University 明治大學 in Japan, returning to teach in the Chinese faculty at Peking University 北京大學. His primary area of research was traditional literature, and he published several books on the subject. Ceramic study was a leisure activity that Hsü pursued with enthusiasm. His book *Yin Liu Chai Shuo Tzhu* was influenced by Japanese scholarship, though it listed a plethora of other references.[153] They ranged from Thang and Sung dynasty poetry to Ming and Chhing dynasty manuals, and English and French connoisseurship.[154] The monograph was arranged in ten chapters, covering kilns, bodies and glazes, colours, designs, inscriptions, various vessel forms, substandard pieces and fakes. Although often derided as being superficial and derivative, Hsü's work is worth attention both as a product of its period and as a reflection of the thorough and wide-ranging knowledge of a serious amateur collector.

Official Historiography: The Standard Histories, Veritable Records and Collected Statutes

Starting in the Han period, official dynastic histories were produced, intended as general reference works for civil servants, scholars and individuals. Those standard histories were compiled in their final form after the end of a dynasty, usually by the ruling power that succeeded it. They served specific political as well as scholarly aims, both during assemblage under a reigning dynasty, and completion under a succeeding dynasty. Completing a dynastic history was a large task, involving government bureaucrats and scholars of Confucian outlook, who brought together large collections of materials and assembled them in a composite, 'cut and paste' manner.[155] This gave rise to somewhat inconsistent and fragmentary compilation that did not include source references. Down to the end of imperial dynastic rule in China, 26 standard histories were compiled, covering every dynasty from Han onwards in some detail.[156]

[153] Wu Yüeh & Chao Ling-Wen (1991), vol. 1, p. 4.
[154] *Yin Liu Chai Shuo Tzhu*, ch. 1, pp. 149–50.
[155] Yang Lien-Sheng (1961), pp. 44–59.
[156] For an overview of Chinese historiography in English, see Needham (1954), pp. 42–54, 73–9, and Wilkinson (1973). For a detailed description of the compilation of official history under one dynasty, the Thang, see Twitchett (1992).

These remarks are included as a preamble, to indicate that official historiography, like so much other primary reference material, was written with specific political ends in mind and in ways that reflected conventional intellectual attitudes. These biases should be borne in mind when quoting selectively from sources to illustrate the history of ceramic manufacture and consumption, for they tend to give a particular tone to research. In many cases, the official records were concerned to comment on things that had not gone well, on missed quotas and on failed commissions. This can give rise to a somewhat negative perspective on events such as the history of imperial ceramic manufacture at Ching-te-chen. In spite of these caveats, the histories also contain interesting and significant information. The body of text is very large, and has been used selectively. Material from monograph sections of the Histories of the Sung, Yuan and Ming Dynasties (*Sung Shih*, *Yuan Shih* and *Ming Shih*), particularly those chapters concerned with state finance,[157] has been consulted. The facts they provide are limited in scope, being mainly contained within general reports on taxation, trading offices, exports and administrative posts.[158]

Much information concerns the management of kilns at Ching-te-chen, and in this context the most extensive reference occurs in *Ming Shih*, where *chüan* 6 of the monograph on state finance is about 'firing and forming' (*shao tsao* 燒造). Official production at Ching-te-chen of porcelains for the court is described, down to the Wan-Li reign period.[159] Itemised is information on quantity, quality, designs and colours, uses, restrictions on private manufacture, official posts and production difficulties. The comments are somewhat derivative and summary, and are mostly drawn from the Ming Veritable Records (*Ming Shih Lu*) and the Ming Collected Statutes (*Ta Ming Hui Tien*). The information is sometimes less comprehensive and detailed than that provided by the gazetteers of Chiangsi province (see pp. 22–4), but is nonetheless worth consulting because of its continuity over several reigns.

Another historical source is the Veritable Records, assembled from court diaries and daily administrative records maintained by officials charged with gathering that material. Only sections of the Veritable Records of pre-Ming date survive, those relating to the brief Thang dynasty reign of Emperor Shun Tsung (+805) and to the Sung dynasty between +938 and +996, whereas the entire corpus of Ming and Chhing Veritable Records is extant.[160] In the context of ceramic production and management, these later documents provide additional and more detailed information concerning porcelain production at Ching-te-chen than that found in the Standard Histories. The Veritable Records of the Ming Dynasty (*Ming Shih Lu*) can be used in parallel with the Standard History, because they are often a more comprehensive source. Indeed, in terms of scope and detail, the Ming dynasty Veritable Records have been assessed as being the single most important source for

[157] *Shih Huo Chih* 食貨志, literally 'Monographs on Food and Goods'.
[158] The monographs on state finance from successive dynasties have been collected and annotated in *Chung-kuo Li-Tai Shih-Huo-Chih Cheng-Pien*, Taipei (1970).
[159] The imperial kiln at Ching-te-chen ceased production in +1608, see Liu Xinyuan (1993), p. 44.
[160] Wilkinson (1973), pp. 66, 68; Twitchett (1992), pp. 119–59.

the study of Ming history.[161] As a third reference, it can be helpful to cross-check facts and events with information provided in the Collected Statutes of the Ming Dynasty (*Ta Ming Hui Tien*). This was the most comprehensive collection of codified abstracts of imperial edicts and instructions ever assembled, and as the compilation was prepared and promulgated by imperial authority it gave great detail about specific requisitions and quotas for porcelain.[162] Statutes pertaining to the Ministry of Works (*Kung-pu* 工部) have been used for this volume, because this was the Ministry with jurisdiction over production of ceramic vessels for court.

During the Chhing dynasty, references to imperial requirements, and information on management of official kilns, is aided by palace memorials (*tang-an* 檔案, and *tsou-che* 奏摺 dated to day, month and year) that survive in collections in Peking and Taipei. Ts'ai Mei-Fen 蔡玫芬 has extracted a lot of useful information concerning ceramic manufacture from those primary records, and her research is reflected in this volume.[163] One useful set of records with regard to the study of art objects is the 'Archives of the Several Workshops of the Imperial Household Department',[164] for it comprises a fairly complete archive of all types of handicraft manufactured in the imperial workshops of Peking in the +18th and +19th centuries, and has been used by several authorities.[165]

LITERATURE IN WESTERN LANGUAGES

By the mid +16th century, European merchants and missionaries were travelling to China on a regular basis.[166] They sent back sundry accounts of life and conditions in East Asia, some of which mentioned ceramics. The earliest voyagers were the Portuguese, among whom friar Gaspar da Cruz is worthy of mention for his painstaking chronicle (+1569) concerning the nature and manufacture of porcelain. His

[161] Farmer *et al.* (1994), p. 81. For discussion of the Ming dynasty Veritable Records see also Franke (1961).

[162] Cf. Farmer *et al.* (1994), pp. 89–90.

[163] Sets of memorials have been published in Taipei and Peking, including *Chhing-Tai Tang-An Shih-Liao Tshung-Pien* 清代檔案史料叢編 (An Anthology of Reprinted Material from the Chhing Dynasty Archives); *Nien Keng-Yao Tsou-Che Chuan-Chi* 年羹堯奏摺專輯 (The Memorials of Nien Keng-Yao); *Kung-Chung Tang Khang-Hsi-Chhao Tsou-Che* 宮中檔康熙朝奏摺 (Secret Palace Memorials of the Khang-Hsi Reign Period); and *Kung-Chung Tang Chhien-Lung-Chhao Tsou-Che* 宮中檔乾隆朝奏摺 (Secret Palace Memorials of the Chhien-Lung Reign Period).

[164] *Yang-hsin Tien Tsao-Pan Chhu Ko-Tso Chheng-Tso Huo-Chi Chhing Tang* 養心殿造辦處各作成做活計清檔. The *Yang-hsin Tien* 'Hall of Moral Cultivation' has been mentioned above in note 124, and its functions are best described in English by Torbert (1977). The Imperial Household Department (*Nei-wu Fu Tsao-pan Huo-chi Chhu* 內務府造辦活計處), was at first located there. In +1759 the workshop was renamed *Yang-hsin Tien Tsao-pan Chhu* 養心殿造辦處. It was managed by officials from the Imperial Household Department, a multi-agency administrative organisation responsible for serving the personal needs of the Emperor, his immediate family and attendants in the private residential quarters of the imperial palace, see Hucker (1985), pp. 354, 520.

[165] For example, Yang Po-Ta (1981), (1987a), (1987b), in his work on enamels and glass. Since January +2000 the Art Museum, The Chinese University of Hong Kong has been collaborating with the First National Historical Archive of China 中國第一歷史檔案館 in Peking to publish a complete set of the archives, see Lin Yeh-Chhiang (Peter Y. K. Lam) (2000), pp. 20, 46.

[166] Travellers and traders had visited Asia in earlier times on a less regular basis, famous among them Jacopo d'Ancona in +1270–3 and Marco Polo in +1275–92. Both of these men travelled the whole distance to China. Trade in ceramics via a series of shorter stages and transhipments was a more common phenomenon, see Chaudhuri (1985), p. 50, maps 8 and 9.

words were quickly promulgated in other languages, and led to a series of +16th- and early +17th-century narratives that served to introduce the subject of China, and china, to a European audience (see Part 7 of this volume).

The most thoroughgoing and specialist descriptions of porcelain manufacture were made by Père d'Entrecolles, in letters to his home mission in France dated +1712 and +1722. Père d'Entrecolles was born in Lyon in +1664, entered the Company of Jesus in +1682 and went to China in +1698. He first proselytised in Chiangsi province, was made general superior of the French mission from +1706 to +1719 and superior of the French residence in Peking from +1722 to +1732, where he died in +1741. His knowledge of Chinese enabled him to translate numerous works, while his enquiring mind led him to detail in his correspondence the raising of silk-worms, the manufacture of artificial flowers and synthetic pearls, and oral inoculation against smallpox, as well as the manufacture of porcelain at Ching-te-chen.[167]

Of the two letters the first is the more complete and informative, while the second adds miscellaneous facts and corrects details presented in the first. Between them they chronicle, with great accuracy and detail, the composition and processing of china stone and china clay; the manufacture of glaze; the working and wedging of clay; the formation of vessels by throwing, turning and moulding; decoration and division of labour; preparation of coloured glazes and pigments; underglaze and overglaze decoration; soufflé blown glazes; gilding; muffle kilns; saggers and sagger manufacture; kiln furniture; and the construction, stacking and firing of high-temperature kilns. It is evident from the content of Père d'Entrecolles' letters that he had consulted Chinese literary sources as well as the evidence of his own eyes. Although he did not cite references, most authorities conclude that he had read the +1682 edition of *Fu-liang Hsien Chih*, that included the text of *Thao Chi* attributed to the Yuan dynasty (see note 112 above). One has to say that for the purpose of understanding ceramic technology at Ching-te-chen, these letters are both clearer, and presented in a more complete and logical sequence, than any of the Chinese accounts that are detailed in this section.

Through intense scrutiny of Chinese literature and illustration, and aided by European accounts and translations, Western factories were at last able in the +18th century to manufacture their own porcelain and bone china.[168] During the last 30 years of the +18th century European factories became so successful that their products superseded imported Chinese porcelain. By the +19th century Chinese

[167] See d'Entrecolles (1781). The letters were published in French by du Halde in +1735, English versions appearing for John Watts in +1736 and for E. Cave in +1738–41 (see Bibliography C). The complete letters were translated by Tichane (1983), pp. 49–128, with bibliographical notes. Tichane (1983) is a good reference source, as it gathers together several accounts of Ching-te-chen in English; his rendition of the letters is used throughout this volume. Père d'Entrecolles' letters were also published in abbreviated form by Bushell (1896), pp. 176–89; translated by Burton (1906), pp. 84–122, and translated by Scheurleer (1982) using reproductions of the French published texts.

[168] The first factory to make hard-paste porcelain was Meissen in +1709, see Kingery & Vandiver (1986a), pp. 163–77. See also Part 7, pp. 749–54 of the present volume.

ceramics had become collectables, but this did not prevent manufacturers and scholars from maintaining an intense interest in the output of Ching-te-chen. Again, French investigation led the field. In +1844 a Chinese Catholic priest, P. J. Ly, sent raw materials to Sèvres in France. These were supplemented by other materials sent from Canton 廣州, and were used by Jacques Joseph Ebelmen and Louis Alphonse Salvetat to analyse body and glaze materials. The results were published in +1850.[169] In +1882 the French consul at Hankow 漢口, Georges Francisque Fernand Scherzer (+1849–1886), journeyed to Ching-te-chen to collect glaze samples.[170] These were used by the Technical Director at the Sèvres Porcelain Factory, Georges Vogt (+1843–1909), in analyses of Chinese body and glaze compositions, and published in Paris in April +1900 (see pp. 216–19).[171] These pioneering scientific studies paved the way for further research into Chinese ceramics, by both Chinese and Western scholars, in the +20th and +21st centuries.

THE +20TH- TO +21ST-CENTURY LITERATURE OF ARCHAEOLOGY

Important though historical texts are, it must be said that a major source of information on Chinese ceramics and kilns is archaeological reports. Consultation of Bibliographies B and C will show how extensively those materials have been utilised, for they are available through publication in an ever-growing number of journals and monographs. Modern Chinese archaeology is increasingly regulated by protocols of recovery and recording that have developed internationally.[172] Over the last two decades, excavation of sites by teams that include archaeologists and scientists from outside China has further aided the exchange of information and techniques in both directions.

Despite this, archaeology in China retains strong contextual links with historical literature, utilising both information provided in gazetteers and histories, and quotations garnered from the extensive literature of connoisseurship. Thus when Japanese scholar Fujio Koyama 富士夫小山 discovered the site of the Ting kilns in +1941, he did so by tracing their location through investigation of *chüan* 6 and *chüan* 10 of the local gazetteer *Chhü-yang Hsien Chih* (+1904) (see pp. 157–8).[173] And in +1998, when surface finds from the Southern Sung imperial Kuan ware kiln site provided material for scientific examination, scientists and archaeologists relied in part on a Sung dynasty scholar's monograph to reference the location (see p. 260).[174]

[169] See Tichane (1983), pp. 186–213.

[170] Scherzer died prematurely from disease contracted when surveying the Indo-China border, prior to France's invasion of southern China in +1884.

[171] Tichane (1983), pp. 430–57; Vogt (1900), pp. 560–612.

[172] New developments in international theory and methodology, in particular that of the so-called New Archaeology that appeared in the +1960s in the USA and Europe, have been gradually learnt in China, see Yu Weichao (1999), p. 27.

[173] Relevant extracts from ch. 1, 6 and 10 are quoted by Feng Hsien-Ming (1987), p. 210.

[174] Li Chia-Chih *et al.* (1999). The text is Yeh Chih's *Than Chai Pi Heng*, see Bibliography A.

Some modern authorities deprecate this continuing trend, such as archaeologist Su Bingqi [Su Ping-Chhi 蘇秉琦] who writes:[175]

> First of all, we have to overcome the limitations of traditional literary records. Archaeology is not simply a matter of authenticating the classics and supplementing historical records: its main aim is to discover material evidence from the ground, as important evidence for the writing of national history. Archaeology is a branch of historical science, but needs to establish its own discipline distinct from that of history.

Though archaeology must establish its own discipline, it will probably remain the case that certain sites will be privileged above others, because of historical associations celebrated in various branches of literature. In the field of ceramics, enormous excitement was generated by the extended excavation of Yuan and Ming dynasty imperial kiln sites at Ching-te-chen, by the discovery of the Northern Sung dynasty kilns for Ju ware at Chhing-liang-ssu 清涼寺, and by the location of the Southern Sung dynasty imperial Kuan ware kiln at Lao-hu-tung 老虎洞. Those sites were thrilling not only for their locations and stratigraphy, but also because they contained ceramic wares hallowed in historical and connoisseurial texts, and admired by scholars and collectors throughout Chinese history.

In similar vein, it seems unlikely that Chinese archaeologists will give up the practice of linking site locations with references in local gazetteers, or of prefacing excavation reports with choice extracts from aesthetes' handbooks and poetry. China's rich, diverse and long-standing literary heritage provides a foil to her extensive and growing archaeological record.

[175] Su Bingqi (1999), p. 17.

INTRODUCTORY REMARKS ON RAW MATERIALS, FIRING, FORMING AND GLAZING

The historical and literary records so far discussed, form the background to the main topic of this book. That subject is the physical nature of ceramic products, and the intervention by man to form, decorate and fire them into a huge range of products. The influence of the culture in which potters operate is an important theme, but the ceramics that a country creates depend primarily on raw materials available, and on the skills and imagination of potters who use them. It is this complex interplay between market demand, making skills and raw materials, that has helped to form and direct the course of world ceramic history.

Ceramics differ from other applied arts (metalwork, glass and textiles, for example) in the unusually direct use that is made of common surface geology. Metal workers use refined elements (such as iron, gold and silver) and alloys (particularly copper-bronzes), while glass-workers try to use the purest oxide mixtures that they can obtain. Potters, by contrast, tend to take their raw materials direct from the ground, often using these materials after only minimal mixing and preparation. Simple though this approach may seem, the clays and rocks themselves can be immensely subtle and complex in their structures and compositions, and may embody at least a dozen separate minerals (such as clays, micas and feldspars, as well as various materials rich in colouring elements such as iron, titanium and manganese). All these varied minerals contribute their own characteristics to the manufacturing methods and sequences, and the drying, and firing behaviours of the different clays.

In China, analysis of raw materials local to kiln sites suggests that most rocks and clays were, initially at least, taken from deposits close to the centres of pottery production. In the West, by contrast, raw materials often needed to be imported over large distances. For example, early European porcelains used a single source of clay in Saxony to provide the prime material for the earliest hard-paste factories such as Meissen (where European hard-paste technology began), Vienna and Venice.[176] Likewise, clays for Staffordshire whiteware production were (and still are) brought

[176] Kingery (1986), p. 170, notes: 'From Meissen, C. C. Hunger in 1717 and then S. Stölzel in 1719 took the secrets of hard-porcelain composition and kiln design to Vienna, where production began in 1720. In +1720 Hunger took the secrets to Venice, and a series of workers from Meissen and Vienna transferred knowledge of the materials and methods to Höchst, Fürstenburg, Nymphenburg, Strasburg, Frankenthal, Berlin, St Petersburg and so on.' Stölzel persuaded the principals of the Vienna factory to use the same Saxon clay as used at Meissen, Raffo (1982), p. 93, while Hunger used 'kaolin smuggled from Saxony' for the first Venice porcelain. *Ibid.*, p. 122.

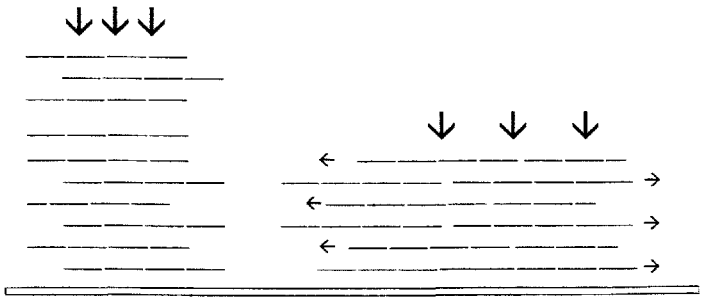


Fig. 6 Compression as the basis of pottery-making

hundreds of miles from the West Country to the Midlands, to an area of England where coal for firing, and clays for kiln-building, were plentiful.[177]

THE NATURE OF CLAY

The essence of ceramics is that dry clay becomes plastic when mixed with water, and can be formed by pressure. When the new clay objects are completely dry they can then be subjected to heat and rendered permanent by firing.

Dry clay has no plasticity of its own, but the addition of 10–25% of water surrounds the dry platy clay crystals and gives plasticity to the material. The water allows the flat crystals to slide over one another under the influence of pressure, causing a shearing effect as the particles separate then realign. When the pressure is released the clay objects retain their new forms through a combination of surface tension and electrostatic forces. Pressure applied to clay-water mixtures is therefore the basis of all pottery-making processes, and the sheared clay particles tend to move at 90° to the source of the pressure applied.

Because of its minute platy crystals, clay has plasticity but little elasticity, so attempts to make the material stretch will cause it to crack and to break. Compression, however, is extremely effective in transforming the material.

Drying (removal of water of plasticity) further stabilises the shapes produced. The process is always accompanied by some shrinkage of the new clay forms (typically about 2–10% linear) as the 'water of plasticity' evaporates. The extent to which clays will shrink depends very much on the fineness and quantity of the platy minerals present. If these crystals are small and abundant then shrinkage will be

[177] Copeland (1972), p. 2. Coal firing for fine ceramics has ceased in north Staffordshire, but the English pottery industry is still sited in the area. The other prime ingredient for +18th- and +19th-century Staffordshire white earthenware, flint, came variously from Gravesend, Brighton, the Isle of Wight and the beaches of Lincolnshire, East Yorkshire and Norfolk (England), and the south-east coast of Ireland. *Ibid.* p. 15.

high; with fewer and/or larger platy materials drying shrinkages will be low.[178] The second vital principle in ceramics is the capacity for these platy minerals to become bonded and transformed by heat in firing, a process described in more detail below.

In practice materials that embrace a wide range of chemical compositions may meet these twin demands of plasticity and successful firing, and many useful pottery materials contain surprisingly little of what are known to geologists as 'true clay minerals'.[179] Plasticity, for example, depends on the platy or fibrous crystal structures of the minerals that are present in the prepared clay bodies. Materials other than true clays can also show these crystal-forms, and these include platy minerals such as micas and talcs. Raw materials rich in micas and talc can also be made permanent by firing, and rocks that are abundant in these 'clay equivalents' have played important roles in world ceramic history.[180] It is therefore possible to have workable and plastic clays that contain next-to-no true clay minerals, but that still fire into successful ceramics. Thus many large and long-running ceramic traditions in China were based on raw materials that were unusually low in 'real' clays, but were rich in various clay analogues, most notably the white micas. Early south Chinese porcelain is perhaps the most important example of this kind of material.[181]

It is also a fact that too much 'real clay' in a pottery body-material may cause problems in production, particularly in the form of high shrinkages in drying and firing that lead to distortion and cracking of the wares. Throwing demands the greatest plasticity of all, but with some manufacturing methods, such as press-moulding, low plasticity is a positive advantage. When press-moulded objects of exceptional scale, such as the terra-cotta warriors, were made, clays with low plasticity, and consequent low shrinkages in drying and firing, were indispensable elements in their production.[182] Some manufacturing methods, such as coiling, can also accommodate and exploit relatively low plasticities in ceramic raw materials.[183]

Origins of Clays

Clays derive mainly from the weathering of igneous and metamorphic rocks, i.e. from rocks that have been molten at some stage in their history, or from rocks that

[178] See Rosenthal (1949), pp. 62–5, for a concise account of these principles. Singer & Singer (1963), p. 62, identify four influences on plasticity: mineralogical composition; particle size and particle-size distribution; cation exchange, cations and pH; and the surface tension of water.

[179] Wood (2002), pp. 21–3.

[180] Glazed steatite from Mesopotamia (−5400 to −4000) is one of the earliest examples of a non-clay material being used as a ceramic body, see Beck (1934), pp. 19–37; Tite and Bimson (1989), pp. 87–99; and Tite *et al.* (1998a), p. 12, for accounts of its nature and use. The material was also used in Western 'soapstone' porcelains in the +18th and early +19th centuries, Freestone (1999), pp. 5–6.

[181] Wood (1986), pp. 261–4.

[182] Zhou Maoyuan (1986), pp. 100–6. However Zhou's suggestion on p. 105 that the non-plastic elements found in the bodies of the terra-cotta warriors were ground and added separately to the clays is probably wrong (see p. 113 of this volume).

[183] The fact that many coiled or hand-built pots were used on fires for cooking made the use of some coarse filler essential. See Cardew (1969), pp. 76–7, and Woods (1986), pp. 157–72 for discussions of the principles involved.

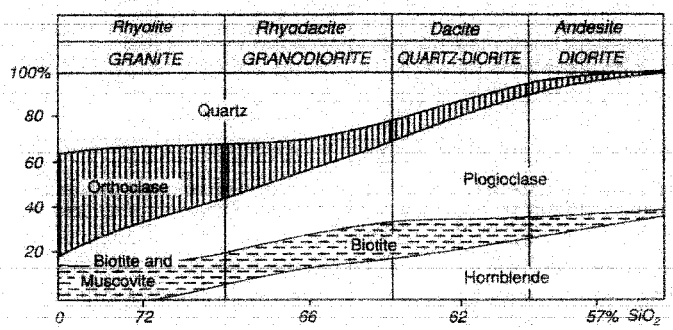


Fig 7 Main minerals in the major igneous rock-types

have been altered by heat and/or pressure.[184] As molten igneous rock (magma) cools down it does not produce one single mineral, but a suite of minerals that have their own definite chemical compositions and crystal structures. The original chemistries of the molten magmas dictate which minerals will appear in cooling, and the minerals crystallise in a definite order from the molten rocks.[185] By far the most important clay-producing rocks in China are those of the 'acid' (high-silica) types. These tend to be low in iron oxides (giving lighter-firing clays) and also low in the oxides of calcium and magnesium, which are two fluxes that can cause clays to melt prematurely in the kiln.[186]

In a typical 'acid' (high-silica) magma the main minerals that will form on cooling are *quartz* (the major mineral in acid rocks) and *feldspars*, mainly *orthoclase* (a potassium feldspar) and the mixed sodium-calcium feldspars of the *plagioclase* types. Various *micas* are also present, such as iron-rich black micas, and potassium-rich white micas, together with traces of an iron- and magnesia-rich mineral known as

[184] 'With the exception of quartz, all abundant minerals in igneous and metamorphic rocks alter at the earth's surface to produce clay minerals. Because of this fact, about 45% by weight of the sedimentary column consists of clays, making them the most important mineral group in sediments . . .'. Blatt *et al.* (1980), p. 265. 'Most igneous rocks appear to have crystallised from a silicate melt.' Whitten & Brooks (1972), p. 234. Exceptions include rocks that have crystallised from glowing beds of volcanic ash (*ibid.* p. 370), while the controversial theories of 'granitisation' propose the creation of some granites from pre-existing rocks at much lower temperatures by the 'action of energetic fluids of appropriate compositions arising from the depths.' *Ibid.*, p. 214. In spite of this 'there is much greater willingness to accept multifactorial explanations [for the genesis of granite] . . . little enthusiasm remains for wholesale granitization – a thesis largely superseded by bulk melting at depth', Pitcher (1993), p. 16. Metamorphic rocks may also weather to clays and Garrels & Mackenzie (1971), p. 167, give an example of a schist that originally consisted mainly of plagioclase and hornblende and which weathered mainly into quartz, kaolinite and the hydrated iron-mineral goethite.

[185] It is interesting that, '. . . with few exceptions the sequence in which minerals weather is the same as the order of crystallization of minerals from a magma – that is, Bowen's Reaction Series. The first to crystallize at depth are the first to decompose at the surface.' Blatt *et al.* (1980), p. 252.

[186] Most Near Eastern ceramics, made before the invention of stonepaste bodies in +10th- and +11th-century Egypt, were made from clays that derived from more basic rocks. These clays were rich in calcium, magnesium and iron oxides and melted easily at high earthenware temperatures (*c.* 1,100–1,150°C). See Tite & Mason (1994), p. 84, table 3, and Zhang Fukang (1992), p. 384, for typical compositions for this clay-type.

hornblende. This mass of inter-grown minerals provides the familiar mineral-mix seen in polished granite surfaces, with the platy micas providing some sparkle to the polished rock.

MECHANICAL WEATHERING

The simplest types of weathering (where rocks break down from external forces) are known as 'mechanical' or 'physical' weathering. This happens where rock is reduced to rubble, gravel or dust by mechanical effects. An example of this process might be the rock-flour that is produced when a glacier (a river of ice) flows over a bed of igneous rock. Boulders trapped at the base of the glacier grind the bedrock to a fine dust as the great weight of ice inches forwards. Eventually melt-water (or even icebergs) from the glacier can transport this rock-flour hundreds or even thousands of miles, where it may be deposited as beds of almost non-plastic glacial silt.[187]

Another important type of mechanical weathering occurs when water penetrates into flaws in igneous rock, then alternately freezes and thaws. As water freezes it expands and drives a wedge between the various mineral crystals.[188] Grain by grain the rock surface is reduced to a powdery dust that shows essentially the same mineralogy and chemical composition as the rock that produced it. Often this dust will be picked up by the wind and redeposited as aeolian clays hundreds of miles from the cold deserts where they were created, with Chinese loess being the most spectacular example of this effect.[189] The bedded dusts that result from this transformation tend to show low plasticities, as they are essentially rock-flours rather than true plastic clays. In some conditions of mechanical weathering both forces will operate. For example, the debris from a melted glacier, known as *till* may be further weathered and removed by these freezing/thawing processes.

CHEMICAL WEATHERING

Mechanical weathering operates in cold and arid conditions, but chemical weathering is typical of warm and wet environments, and produces far more rapid change. Chemical weathering involves true chemical reactions and the process creates a wealth of new minerals within the weathered rock, many of them clays. In fact chemical weathering is the main source of true clay minerals in sedimentary deposits, but their genesis is highly complex, and not always easy to model or explain.[190] It usually involves attack by mildly acid water, but may involve far more

[187] 'This is thought to be the origin of the Fremington clay in North Devon, a large mass of Pleistocene age found sitting on top of rocks of Carboniferous age.' Cardew (1969), p. 19.

[188] 'The physical basis of frost wedging is the 9.2% volume increase in H_2O during the phase change from water to ice.' Blatt *et al.* (1980), p. 247.

[189] 'In most environments on the earth's surface, mechanical weathering is of almost negligible importance compared with chemical weathering'. Blatt *et al.* (1980), p. 247. Chinese loess, however, at about one million square kilometres of land-cover, must stand as the most important exception to this principle.

[190] 'From the point of view of a chemist, the study of chemical weathering is a nightmare in which nearly all reactions are incomplete, chemical components come and go at unpredictable times, temperature varies irregularly, and thermodynamically unstable compounds are frequently precipitated.' Blatt *et al.* (1980), p. 246.

acid, organic environments, highly saline conditions, or strongly alkaline conditions rich in calcium and/or magnesium salts. The first situation (slightly acid water) is by far the most usual.[191]

The prime agents for the chemical weathering of rock are water and carbon dioxide, and a reasonably ambient temperature speeds the chemical reactions.[192] The water and the carbon dioxide are usually present as rainwater, which is slightly acid due to a small content of dissolved carbon dioxide. When water and carbon dioxide react with the minerals that are present in hard igneous rock, new minerals are formed, and this is the main process in the genesis of clay. Life too can play a part in this process, with both plants and bacteria contributing to the effect.[193]

Granite-type rocks (granites and granodiorites), and their volcanic equivalents (ryholite and andesite), are the source of China's most important pottery clays, particularly those used for northern porcelains and stonewares. These hard and tough rocks consist largely of intergrown masses of minerals that have crystallised within the cooling rock. These minerals are quartz, potash feldspar, sodium-plus-calcium feldspar, black mica and white potassium mica. Of this group only the micas have platy structures, but their particle-sizes tend to be too large to give much plasticity to the crushed or mechanically weathered material. However, when acid rocks are attacked by water and by carbon dioxide, in the presence of warmth, numerous changes take place (Table 2).

As a result of chemical weathering, the coarse non-plastic and blocky crystals of feldspars convert to dusty masses of secondary minerals (clays, micas and fine quartz) many of which are highly plastic. Most of these secondary minerals are so fine that their structures can only be resolved by scanning electron microscopy. In terms of weight, about 15% of the original acid rock might convert to true clay minerals (such as kaolinite and halloysite), and to clay analogues such as illite and hydromica), while the remaining materials will be mainly unaltered quartz together with some unaltered micas.

Although only the feldspars and the micas convert to these new clay minerals, the whole rock crumbles as chemical weathering proceeds. The decay of the rock is assisted by water finding its way between the new clay crystals through capillary effects, increasing their bulk and forcing the larger crystal grains apart. Life too plays a part in this process, both as visible rootlets and invisible bacterial action. Thus the hard acid rock becomes a semi-plastic gritty mush as chemical weathering and organic attack cause its solid structures to decompose.

[191] See Chamley (1989), p. 22, who gives the names *acidolysis*, *salinolysis* and *alcalinolysis* to the more extreme conditions, and *hydrolysis* to the more typical process.

[192] 'For every 10°C rise in temperature the rate of chemical reaction increases by a factor of 2.' Velde (1995), p. 47.

[193] This process is sometimes caused by hydrolysis – literally destruction by water – and is essentially a 'chemical reaction between a salt and water, to form an acid and a base. The widely distributed aluminosilicates (for example, feldspars, pyroxenes, amphiboles, micas) constitute salts of weak acids, which react with water to form dissolved silicic acid and various bases, as well as secondary minerals like clays.' Chamley (1989), p. 22.

Table 2 *Genesis of clays from granite*

Unweathered granite consists of:	*Weathered granite consists of:*
Primary quartz (*coarse, non-plastic*)	Primary quartz (*coarse, non-plastic*) plus a small amount of dissolved silica
Biotite (black mica)[a] (*coarse, slightly plastic*)	Potassium and magnesium carbonate (*soluble salts*); limonite (yellow iron oxide) (*non-plastic*) plus clay (plastic) and fine secondary silica (*fine, non-plastic*)
Muscovite (white mica) (*coarse, slightly plastic*)	Exfoliated illite, illitic mixed layers, vermiculite (*fine and plastic*) plus some residual potassium mica (*coarse, slightly plastic*)
Lime feldspar (*coarse, non-plastic*)	Clay (*fine and plastic*) and secondary calcium carbonate (*slightly plastic*)
Potassium feldspar (*coarse, non-plastic*)	Hydromica (*fine and plastic*) secondary quartz (*fine, non-plastic*) ('sericitisation') and/or: Clay (*fine and plastic*); secondary quartz (*fine, non-plastic*); potassium carbonate (*a soluble salt*), (a process known as 'kaolinisation') and/or clay (*fine and plastic*); secondary sodium feldspar (*coarse, non-plastic*)
Sodium feldspar (*coarse, non-plastic*)	Clay (*fine and plastic*) secondary quartz (*fine, non-plastic*) sodium carbonate (*a soluble salt*)

[a] A distinction has to made between the primary micas, such as biotite and muscovite, that have crystallised from the cooling rocks, and the secondary micas that are formed from the chemical weathering of these materials, and also from the breakdown of feldspars. The term illite is often used in a general sense for secondary clay-sized micaceous fractions in sedimentary materials and, more specifically, for a particular micaceous mineral with a composition similar to muscovite's, see Moore & Reynolds (1997), pp. 150–1. The name derives from the state of Illinois and was coined in +1937, Grim *et al.* (1937), pp. 813–29. True illite contains slightly more water and less potassium in its structure than muscovite, cf. Chamley (1989), p. 12, but its nature and proper identification have been the subject of much debate. As Moore & Reynolds (1997), p. 151, note: 'Bravaisite, degraded mica, hydromica, hydromuscovite, hydrous illite, hydrous mica, K-mica, micaceous clay, illinois-geological-surveyite, and sericite are some of the terms that have been used approximately synonymously, reflecting the variable and heterogeneous nature of this material . . . Discussions about the naming of minerals, this one in particular, can be vigorous and even acrimonious.' Today the term 'illitic material' is often preferred for the more general use of the word (clay-sized mica), with 'illite' reserved for the mineral itself which, like most clay-minerals, should be considered as an end member of a series, rather than a single pure substance. In the case of illite the mineral might be intergrown with smectites, chlorites or montmorillonites, see Brindley (1984), pp. 431–2, in Brindley & Brown (1984). Interlayering of this kind tends to be the rule rather than the exception in clay mineralogy.

As heavier rain falls, the rotten rock will gradually wash from the crumbling rock-face. In fast mountain streams most of the weathered material will be carried downhill but, as the speed of the streams slows, the coarser materials (mainly quartz and coarse mica) will be deposited as a gritty sand. The lighter platy minerals (clays and fine micas), and the fine secondary quartz, continue their journeys, giving the flood-water a muddy appearance. The soluble materials formed during the chemical weathering process (mainly carbonates of sodium, magnesium and potassium, together with some silica) dissolve in the water and are carried with it.

The fine clay minerals, transported by streams and rivers, tend to settle as muds where the water-flow abates, typically in lakes, in river flood plains, and also in estuaries, where rivers meet the sea. Estuaries are particularly effective in removing clays from suspension as the brackish water causes clay to settle for electro-chemical reasons, while marine plant life traps still more clay. This makes ancient estuaries and coastal swamps rich sources of sedimentary clay and many stoneware and porcelain clays of north China were laid down under deltaic conditions.

The dissolved salts (mainly those of sodium) eventually reach the sea, where the sodium ions combine with chlorine anions to provide dissolved sodium chloride (salt). The saltiness of the sea is therefore a relic of vast quantities of soda feldspar in continental igneous rocks that have been transformed to clay through millions of years of chemical weathering – while the beaches of fine quartz sand, often found at the lands' margins, are a further product of the process.

The fine insoluble, clay-rich materials, carried in rivers and streams, eventually settle and produce extensive beds of mud. These muds become buried by further inundations, or by the folding of sedimentary strata. The material then dries to some extent and consolidates into the stiff, waxy material known to potters as secondary sedimentary clay. If acid igneous rocks have been their source, these clays may consist largely of kaolinite, with lesser amounts of fine quartz, various micas, and smaller amounts of iron and titanium minerals.

Tropical Weathering

In temperate conditions the effects of rainwater and ground-water weathering tend to be superficial, extending only a few centimetres into the fresh rock. As the altered rock is washed away, weathering attacks new surfaces, gradually removing the fresh crystalline rock layer by layer. In tropical climates, by contrast, *in situ* weathering to a depth of 30 to 90 metres is not uncommon. Thus substantial igneous outcrops, or whole hillsides or mountainsides, may be changed into rotten rocky materials that may easily be mined by mattock or spade, a common situation in south China. If the original grain-size of the crystallised rock was small, due to fairly rapid cooling of the parent magma, this altered material may resemble deposits of gritty clay, and also show some slight plasticity. Unlike most sedimentary clays, these primary materials contain substantial amounts of unaltered quartz and mica, together with some semi-altered feldspars. Thus in their chemical and mineralogical natures, they

lie somewhere between the original, unaltered igneous materials, and true sedimentary clays. These are known to potters as 'primary' or 'residual' clays, and raw materials of this type were often mined and processed in south China for making ash-glazed stonewares.

HYDRO-THERMAL ALTERATION

Perhaps the most dramatic of all clay-producing processes occurs when igneous rocks are attacked from below, from the depths of the earth's crust. The main agent in this process is super-heated steam that may penetrate faults or fractures in igneous rock hundreds of feet beneath the earth's surface at temperatures as high as 500°C (dull-red heat). This steam or pressurised water may contain dissolved carbon dioxide and/or silica and can bring about similar kaolinising and sericitising effects to those produced by surface weathering. However the depths of hydrothermally-altered rocks often far exceed those seen in tropical weathering, to the extent that many deposits remain unproved.[194]

VOLCANIC ALTERATION

One final type of clay-forming mechanism that is important in Chinese ceramics involves the alteration of volcanic ash. Acid (i.e. high-silica) magmas tend to form viscous masses of semi-liquid rock. These can freeze in volcanic pipes causing enormous build-ups of pressure from the molten rocks and gases behind. When the pressures become too great huge explosions result, giving clouds of volcanic ash that rain down to form sedimentary rocks with obviously bedded structures. The quartz-feldspar rocks produced from these events may be further altered by 'high-temperature saline hydrous fluids' that change the potash feldspars to secondary potassium mica (hydromica) and to secondary quartz.[195] Thus fine-textured volcanic rocks, produced in this manner, may consist largely of quartz, hydromica and soda feldspar. In some cases the soda feldspar is further altered to clay, giving rocks that are composed of quartz and hydromica, together with small amounts of primary clay.[196]

Because of their high contents of fine secondary mica, the crushing and refining of these rocks can produce materials that behave like clays of moderate plasticity, though their true clay contents may be only 10% or less. Rocks of this style that are unusually low in iron and titanium minerals are known as porcelain stones. They occur in huge deposits in southern China, southern Korea, and on the western island of Kyushu 九洲島 in Japan.

[194] Some famous examples of residual clays formed by hydrothermal activity are the Cornish china clays, created from the local granite. Problems in pumping out the vast pits created by clay mining in Cornwall (together with the associated Cornish stone used as body-flux) prevent deeper opencast mining than presently employed. See Exley (1959), pp. 197–225, for a detailed account of the processes involved in the creation of Cornish china clay rock.

[195] Tite *et al.* (1984), pp. 147–8.

[196] *Ibid.*

MAIN CLAY-TYPES IN CHINA

Most of the important clays and rocks used in the history of Chinese ceramics tend to fall into one or other of the categories described above, particularly the following four:

Mechanically weathered rock-flours produced by the freezing and thawing of desert igneous rocks. These fine powders are picked up by the wind, stirred in the higher atmosphere, and deposited hundreds of miles from their desert sources, as deep beds of loosely compacted rock dust. Chinese loess is the prime example of this process.

Chemically weathered igneous rocks that have had their fine clay and mica fractions removed by rainwater, and these platy minerals lain down in ancient estuaries as clay-rich muds. Such clays are now often deeply buried beneath coal and limestone strata and are important raw materials for both low-fired and high-fired ceramics in north China.

Chemically altered igneous rocks that have been subjected to deep tropical weathering that has penetrated some tens of metres into the original rock. Deeply weathered igneous rocks are abundant in southern China, where they were (and are) often processed for the making of stonewares.

Acid (high-silica) volcanic ash that has settled into deep beds. Rocks of this style are often natural mixtures of quartz and secondary mica. They need pulverising and refining before they can become plastic, and their typical employment has been for south Chinese porcelains.

The first two clay-types are characteristic of north China, while the latter two are most abundant in the south of the country. In fact one of the most unusual and significant features of Chinese ceramics production is that there are so few exceptions to this north/south principle, in terms of its ceramic resources.

THE NAN-SHAN CHHIN-LING DIVIDE
南山秦嶺大分水嶺

That it is possible to make such clear-cut distinctions between the raw materials used for northern and southern ceramics in China is due to an important geographical, cultural and historical division that is known as the Nan-shan Chhin-ling divide, after two mountain ranges that occur along its length.[197] This divide runs just north of the Huai river 淮河 and the Chhin-ling mountains 秦嶺山, and onwards westerly towards Tibet and the Nan-shan mountain range 南山. It separates the wheat and millet lands of north China's Great Central Plain and loess plateau from the mainly rice-growing south; it also separates two very different areas of mean-temperature and rainfall. At various times in China's history the divide has

[197] Tregear (1980), p. 5.

also served as a political boundary and still represents, in Chinese consciousness, the natural division between the north and the south of the country.[198]

One of the most important later +20th-century discoveries concerning Chinese ceramics has been the identification of the profound differences in composition that exist between ceramics made above and below this divide.[199] These differences apply to ceramics made as far north as the Great Wall, and as far south as China's borders with Vietnam. Thus they do not refer solely to the historical 'north' and 'south' of China, i.e. the areas around the Yellow river 黃河 and Yangtze river 長江 basins, respectively. A possible reason for this marked difference between northern and southern ceramic materials in China has been suggested by one of the authors (NW) from an examination of recent plate-tectonic theory.[200] This geological work has proposed that north China and south China were once separate landmasses that collided during the Triassic period, when north China struck Siberia some 225–195 million years ago,[201] an event summarised by its Chinese authors thus:[202]

> What we are concerned with is a series of northwards migrating blocks, moving at different rates. Their collision was often due to a quicker block catching up with the slower one in front of it . . . After the collision of north China with Siberia in the late Permian, there came the head-on collision of south China, which caused the significant mountain building of the Indosinian Orogeny in the Ladinian.

Earlier in the chapter the authors mention that:[203]

> The great Indosinian Orogeny . . . caused the final retreat of the sea in eastern China and the mountain-building of Qinling [Chhin-ling]. This appears to indicate the final welding (from east to west) of south and north China.

The distribution of these ancient blocks, before their collision, is shown below.

It seems possible therefore that the separate geological histories of the North China Block and the South China Block, before this collision, account not only for the very obvious topographical and geographical differences that exist between north and south China, but also for the clear compositional differences that have emerged between the northern and southern ceramics.[204]

One result of this tectonic collision was the raising of the Chhin-ling mountain range, and it is the clays that are found north of this divide that will be discussed first, in Part 2 of the book. The north–south division of China in ceramic terms will also be discussed in greater detail in Part 2.

[198] These various cultural and geographical divisions are well displayed in Blunden & Elvin (1983). See the maps on pp. 22–23, 29, 98, 123 and 179.
[199] Sundius & Steger (1963), p. 433, were the first to describe this phenomenon.
[200] Wood (2000a), pp. 15–24.
[201] See Piper (1987); Ren Jiashun *et al.* (1987); and Xu Guirong & Yang Weiping (1994), for detailed treatments of this subject.
[202] Xu Guirong & Yang Weiping (1994), p. 329.
[203] *Ibid.* pp. 325 and 329.
[204] Wood (2000a), p. 16.

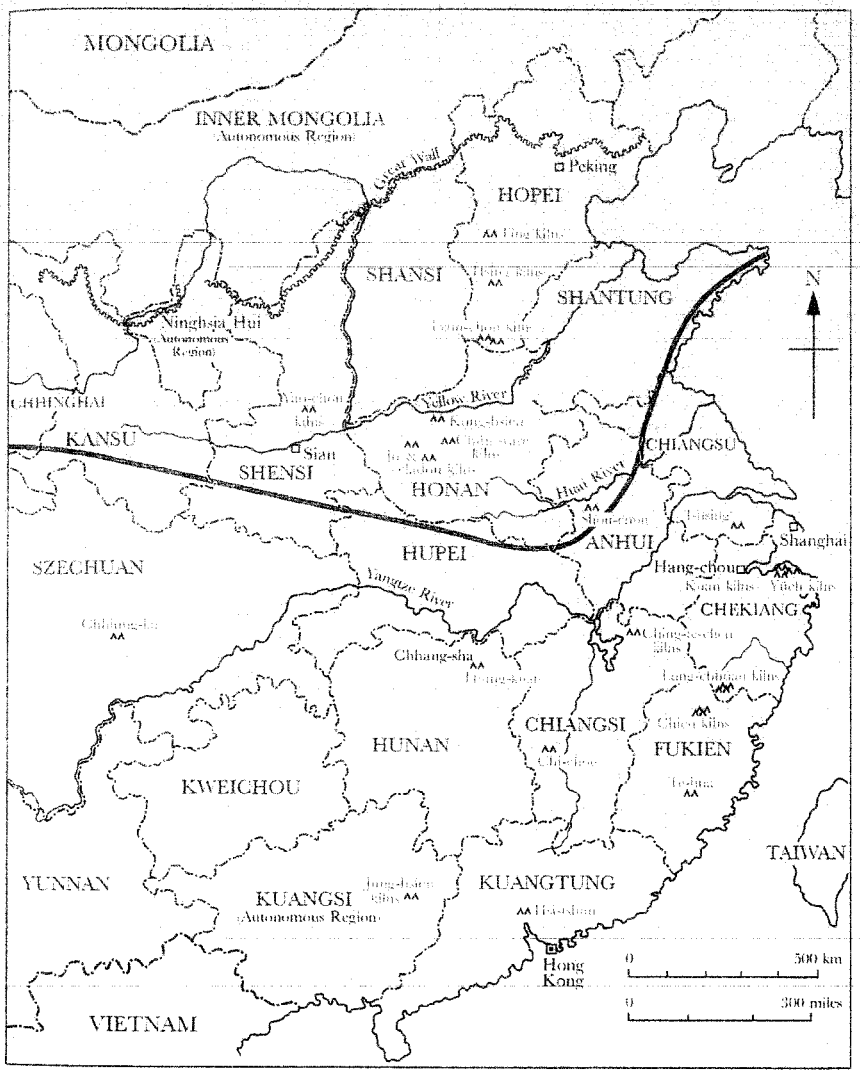


Fig. 8 Map of China and the Nan-shan Chhin-ling divide, showing main cities, rivers and kiln sites

KILNS AND FIRING

Moving from clays, the next topic that will be considered in Part 3 of the volume is how clays were transformed into ceramics through the intermediary of heat. Sustained application of heat to clay's platy minerals changes the temporary stability achieved by drying to the permanent strength associated with fired ceramics. Firing can also involve some shrinkage, particularly in the higher temperature-ranges. At low temperatures (600–900°C) clay minerals sinter together, giving low strength with high porosity. Greater heat (900–1,100°C) generates some glass between particles, which further bonds the clay and leads to improved strength. Orange-to-white heat (1,200–1,350°C) causes the platy particles to break down further and to re-form into a felted mass of needle-shaped mullite crystals. Together with the increasing amounts of body-glass that appear at high temperatures, these inter-grown mullite crystals supply the exceptional strengths associated with stonewares and porcelains. Not all clays can survive these high temperatures, however, and many common earthenware clays will melt into black glasses at the temperatures used in stoneware and porcelain kilns. The temperatures involved in firing ceramics are substantial. A good red heat is necessary for firing the simplest types of pottery (porous earthenware). Orange-white heat was used to fire the wealth of stonewares made in south China from the early Bronze Age onwards, while a white heat verging on blue was used for the finest qualities of northern porcelain, such as Hsing wares 邢窯 from Hopei province of the +10th century.[205]

At the temperatures involved with Chinese porcelain manufacture (1,250–1,400°C), firing tends to be a spectacular event, and the interior of a large stoneware or porcelain kiln at the height of a firing can be an awesome sight. A few inches of brickwork separate the viewer from the torrent of flame and the incandescent wares within. The ground the viewer stands on is hot, and resonating with the pulse of the fire, and the eyes have to be shielded from the intense glare as the ceramics or saggers shimmer in the whiteness. The firing of porcelain is a dramatic event, but the feeling that weeks or months of effort have been committed to an extreme and difficult finishing process is not restricted to porcelain. It must have been common sensation to potters through history, not least because firing is as capable of destroying wares as it is of transforming them. This is surely one of the reasons that many potters invoked the spirit of a Pottery Deity to aid them (see pp. 166–7, 205–6 and 243–4).

Even when a kiln-firing is successful a proportion of the kiln's load may have to be sold as 'seconds', due to faults such as underfiring or overfiring, poor oxidation or reduction, or molten glazes touching something in the setting. A few wares too may need to be discarded completely, due to bursting or cracking in the kiln, to collapse through excessive heat, or perhaps to damage caused by some movement within the kiln. As Père d'Entrecolles recorded of Ching-te-chen:[206]

[205] Guo Yanyi (1987), pp. 3–19, provides a useful overview of the temperatures and materials used in the production of early Chinese high-fired ceramics.

[206] Tichane (1983), p. 96, translation of Père d'Entrecolles' letter of +1712.

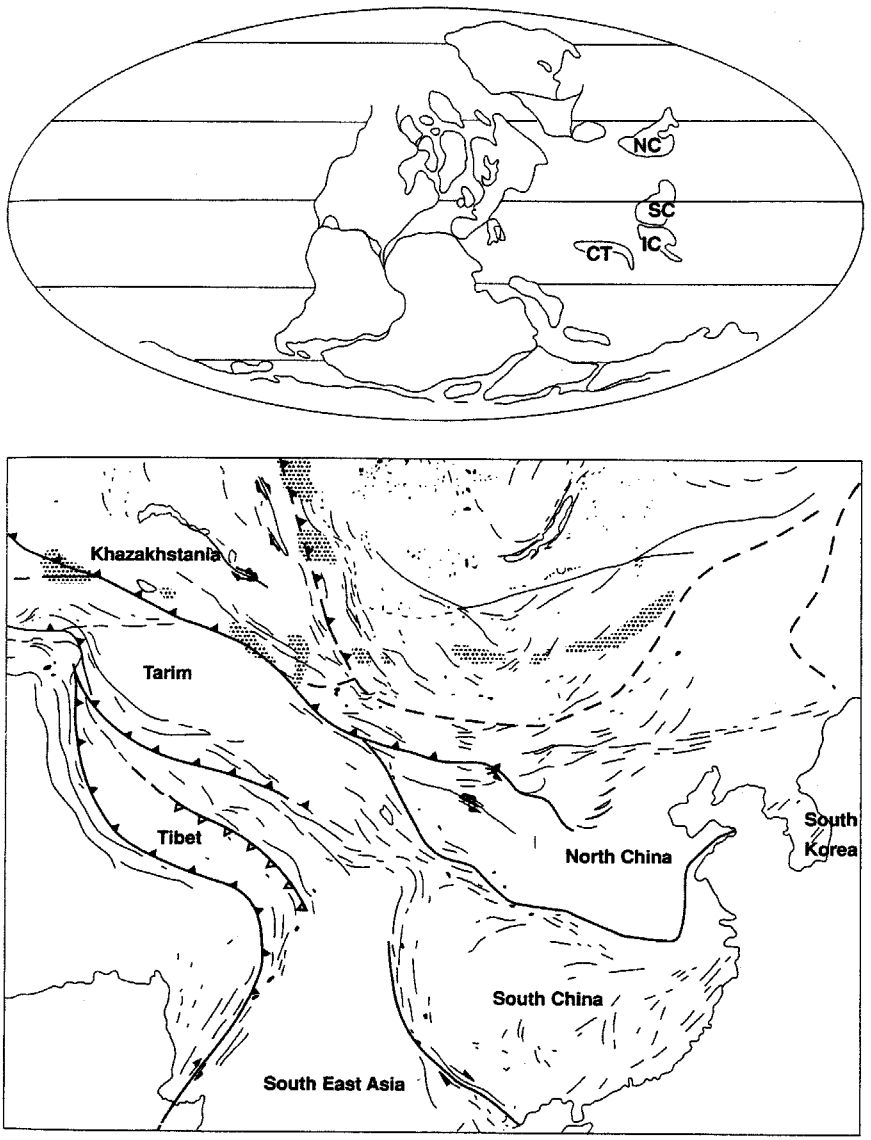


Fig. 9 The North China (NC), South China (SC), Indo-China (IC) and Central Tibet (CT) blocks in the Permian period, before their fusion in the Triassic period

It is rare for a furnace firing to be entirely successful, as often it is entirely lost. Sometimes when one opens the furnace one finds that the porcelain and saggers are reduced to a single mass, as hard as a rock, because of too fierce a fire; or, some badly conditioned saggers can ruin it all; or, it may not be easy to regulate the fire the way it should be; or, it may be that the nature of the weather instantly changes the nature of the fire and the quality of the subject on which it works. The quality of the wood too effects the firing.

Perhaps more than anything else it is the irreversibility of firing that makes ceramics such a high-risk process. Glass and metal objects can often be recycled, but ceramics that have been spoiled in firing can only be thrown away. While this is a boon to ceramic historians and ceramic technologists, who derive vital information on the provenance of wares and changes in style and technical processes from mounds of kiln wasters, the scrapping of work ruined in firing has always been a major frustration of the craft.

Nonetheless, it is this combination of uncertainty of outcome with large-scale production that supplies much of the life and variety to ceramics. The relative ease with which clay vessels can be formed means that most ceramics have been produced in large batches, rather than as single 'finely wrought' objects. Potters take their batches of ware through successive stages of manufacture with images in their minds of how they will appear when they are drawn from the kiln. Indeed this is one of many parallels between ceramics and horticulture. The drawing of a kiln is the ceramic equivalent of a harvest, with the careful following of traditional practice leading to an uncertain, but usually fruitful, end.

As with horticulture, too, much of the produce will look as hoped, while some will fall short of these ideals. It is on this assumption of proportional rather than absolute success that most potters operate, and this is a rather different level of control to that practised in most other crafts. One positive aspect of the uncertainties and subtleties inherent in ceramic production is the pleasant surprises that firings often afford. Occasional pieces will amaze by their quality, causing the potters to speculate how such effects were achieved, and will often lead to attempts to repeat these effects in the next cycle of production.

Thus ceramics has its own dynamic that often leads to improvements arising from the complexities of the processes used, and the shrewdness, curiosity and ambitions of its practitioners. Such a process was observed and recorded by Père d'Entrecolles +1722:[207]

I was brought a piece of porcelain called *yao-pien* 窯變 or flambé . . . The worker had planned to make soufflé red vases. One hundred pieces were lost, and the one that I spoke of came from the kiln resembling a piece of agate. If one wanted to run the risks and the expense of different attempts, he could finally find the technique which chance had produced only once. It is said that it was in this way that the mirror-black *ou-kin* [*wu-chin* 烏金] glaze was discovered. A furnace accident produced it and now it is made that way.

[207] Tichane (1983), p. 120, translation of Père d'Entrecolles' letter of +1722.

Investigation and exploitation of chance effects are therefore one aspect of the potter's response to his craft. Chance outcomes have benefited Chinese ceramics in many ways, often because of the high temperatures used and the range of kiln atmospheres employed. Nonetheless, as Père d'Entrecolles infers in his letter, another prime motive in the potter's mind must be the limitation of risk. Because of the hazards and difficulties of ceramic manufacture, much of its history in China has been driven by the need to maximise certainty of production through improved manufacturing methods and sequences. This has often involved increasing division of labour, the use of moulds, the design of more reliable kilns, and the discovery of still more economical and reliable ways of setting the objects during firing.

Such considerations, of course, apply to most ceramic traditions, though certainty of outcome was occasionally sacrificed in China for the sake of a few fine pieces, with the production of monochrome copper-red wares at Ching-te-chen in the early +15th century being the most famous example. Many +18th-century continental European porcelain factories too were very wasteful to run because of unreliable body and glaze recipes, and through the use of over-complicated designs. Such factories tended to be subsidised royal or state concerns, and the prestige gained from successful objects was considered to be worth the risks incurred.

The Process and Stages of Firing

At the heart of this subject of firing lies the uniquely ceramic effect of 'transformation', where the clay body is converted into earthenware, stoneware or porcelain by very substantial inputs of energy. Each stage of this process involves some very specific chemical and structural changes, and these occur successively within a range of possible firing temperatures from red heat (about 650°C) to blue-white heat (about 1,400°C). This entire temperature-spread has been used in China at various times in its history for different wares. Firing temperatures gradually increased over the millennia, particularly from the early Neolithic period to the +11th century. For this reason some notes on the chemistry and physics of ceramic change may be useful at this point, in order to illustrate the progressive changes that ceramics undergo during this vital and concluding stage in manufacture. These notes can be taken as typical for highly kaolinitic bodies, such as northern stonewares or porcelains, while the rather different firing-behaviours of southern high-temperature materials are described in due course.

If the firing of clay had to be summarised by a single phrase it would be that it is mainly concerned with the removal of water. Water exists in dry clay in three states: mechanically combined water, adsorbed water and chemically combined water. It is not until all three forms have been thoroughly eliminated that true ceramic change can be said to have occurred.

Water is usually added to clay during its preparation, to make some 10–30% of the clay's plastic weight. The amounts used depend ultimately on the materials' mineralogies and the range of particle-sizes present and they tend to be judged

subjectively by potters on the basis of workability; they may also be adjusted for different methods of making. Water activates the clay's potential plasticity by surrounding and lubricating the platy minerals in the clay body, allowing them to slide under the influence of pressure, and allowing plastic forming to occur. Once a pot has been formed (a process described in greater detail later in this section and in Part 4), the 'water of plasticity' is redundant. It is allowed to evaporate gradually, usually by placing the newly made wares on racked boards inside the workshop. Capillary effects from fine gaps between the clay's particles assist this drying process by helping to remove water from deep within the thicknesses of the wares.[208] Great care has to be taken to ensure that drying takes place evenly. Drying is always associated with shrinkage, and unequal shrinkage, due to unequal drying, usually leads to cracking as an object tears itself apart. Sometimes positive heat may be applied at the last stage of drying, when shrinkage is complete, perhaps by putting the nearly dry wares in the sun (common in south China) or by placing the wares on the heated platform *khang* 炕 (more usual in the north).[209] Once positive drying has been undertaken the wares are committed to the kiln, as objects that are allowed to cool again may become 'shop-rotten' through adsorption of atmospheric water.[210] Once the wares are dry to the touch they can be placed in the kiln, the kiln door bricked and sealed, and the firing started.

The first stage of firing is essentially a continuation and conclusion of drying. Some few per cent of the original water of plasticity (the 'mechanically combined water') remain between the clay's mineral particles, and this 'pore water' is capable of causing the raw clay objects to explode violently if it turns to steam too fast. In fact too much heat at this stage can cause the inside of the kiln to sound like a firework finale as the vessels self-destruct. The first 200°C of any firing are therefore a dangerous stage for the wares, and one that has to be taken slowly and carefully. A firing rate of about 30°C an hour might be used for small or thin objects, but 10°C/hour or less may be necessary for thicker and heavier wares, such as bricks and tiles.

Although most of the mechanically combined water will have been driven away once the kiln's interior reaches about 150°C, it is still hazardous to steepen the temperature-rise at this stage, as *adsorbed water* may still be present in the clay, and this too presents a danger as it turns to steam. The nature of *adsorbed* water is a very thin film, perhaps only a few molecules thick, attached to the surface of the clay and mica crystals, bonded to the unsatisfied radicals on the crystal surface.[211] In this sense it is more tenacious than the residual pore water, and needs more energy (i.e. greater heat) to be dispelled. However, once the overall temperature of the kiln reaches about 200°C (the temperature of a hot oven) these first two types of water

[208] The importance of capillarity, in both drying and firing, is well described in Kingery (1960), pp. 197–8, and in Kingery & Vandiver (1986a), pp. 217–23.

[209] The brick-built *khang* is a feature of domestic architecture, used both as a radiator and a sleeping platform. It is heated underneath, generally with coal briquettes.

[210] Cardew (1969), p. 172.

[211] 'There is always a layer of water around each clay particle, but its thickness varies from one to four molecules, according to prevalent humidity.' Hamer & Hamer (1997), p. 280.

will have been eliminated from the dry clay, and the rate of temperature-rise can be steepened to about 100–150°C/hr. This early stage in firing is often called 'water smoking' in fuel-burning kilns, as elimination of pore and absorbed water produces steam, and this coincides with the rather inefficient (smoky) combustion of the fuel, typical of low kiln temperatures. Steam may also be liberated from the kiln's structure at this stage, as water absorbed from the ground, and also from the atmosphere, is boiled away.

The next stage of firing (*c.* 200–350°C) involves the charring (though not the burning) of organic material present in the clays. Organic material is far more abundant in sedimentary northern stonewares and porcelains than the rock-based southern ceramics, and a faint compost-like smell is often associated with the charring of this material. At 573°C the quartz sand, that is present in all clays to a greater or lesser extent, undergoes a 2% volumetric expansion as the atomic bonds within the SiO_2 molecule straighten. This is known as the alpha-beta quartz inversion, and it is reversible (β to α) on cooling. Quartz expansion does not usually present a problem with raw-clay objects on the upward ramp of firing, as the porous nature of the clay material accommodates to the change. But underfired wares are vulnerable in cooling, as they may not have enough strength to survive this small contraction in their sand fraction, and can develop overall networks of cracks as they cool. In a similar way, when dense high-fired wares such as stonewares and porcelains are subjected to too-rapid firings in enamel kilns, the sudden quartz expansion at 573°C may also lead to cracking.

The alpha-beta quartz inversion occurs in the middle of a change that is central to the process of firing, i.e. the conversion of clay to ceramic. All clay and mica minerals contain chemically combined water, bonded strongly within their molecular structures. This water was introduced when chemical weathering formed the minerals, many millions of years ago, as described on pp. 44–7. This water is more firmly bonded than the adsorbed water and needs greater energy to displace it. The process of dehydroxylisation (that is the removal of hydroxyls) begins in a low-key way at about 350°C, and is usually complete by the time the kiln reaches 650°C. With a pure kaolin material this 'water of crystallisation' can amount to as much as 14% by weight of the dry clay, but most clays tend to be lower in true clay substance, so lose some 3–10% weight on firing. Once dehydroxylisation has occurred an entirely new mineral ('metakaolin') has formed, and the clay has converted irreversibly to pottery, through the following reaction:

$$Al_2O_3{\cdot}2SiO_2{\cdot}2H_2O \text{ (kaolinite)} + \text{heat} \rightarrow Al_2O_3{\cdot}2SiO_2 \text{ (metakaolin)} + 2H_2O \text{ (water)} \uparrow (350\text{–}650^\circ C)$$

True fired pottery can therefore be created at 650°C, but kiln-firings rarely terminate at this temperature because the fired material is mechanically very weak, and prone to cracking in cooling, particularly as the wares pass through the β to α quartz transition. The only strength present in clay at this stage is that derived from solid-state sintering. Solid-state sintering is ceramic strength that forms in the

absence of body-glass and is caused by the mineral particles' vibrating with the rising energy introduced by firing and 'friction welding' themselves together at points of contact. Sintering is both the simplest and the weakest way for attaining ceramic strength.[212]

As the firing progresses carbonaceous materials begin to burn properly at 800°C and above, and sulphur dioxide, chlorine and fluorine may also start to be liberated from some clays if the kiln's atmosphere is suitably oxidising. With sedimentary clays rich in organic materials, such as northern Chinese stonewares and porcelains, these gases can sometimes be sensed around the kiln in the form of choking fumes. Small amounts of body-glass may also now begin to form in the wares, mainly from the potassium and sodium ions that are present in the clay bodies combining with fine silica particles. These supplement the low strength afforded by sintering, and provide some glassy 'glue' between the bodies' mineral-grains.

As the kiln-temperatures rise further (say, 980–1,100°C) the development of body-glass accelerates, assisted by some further changes in the metakaolin particles as they convert to spinel. This releases some fine secondary silica as the metakaolin crystals break down and re-form, in response to the rising input of energy:

$$2(Al_2O_3 \cdot 2SiO_2)\ \text{(metakaolin)} + \text{heat} \rightarrow 2Al_2O_3 \cdot 3SiO_2 \cdot \text{(spinel)} + SiO_2\ \text{(silica)}\ (890\text{–}1{,}100^{\circ}C)$$

The superfine secondary silica (about 12%), liberated from the breakdown of the metakaolin crystal, reacts easily with any alkaline ions present in the clay to form body-glass. This bonds the mineral particles more firmly and improves the fired strength of the wares, effects that are supplemented by further sintering. Temperatures of about 1,000°C were often used for biscuit-firing in China as this gave the wares sufficient strength to stand the stresses of cooling, and also handling in glazing, but still left them porous enough to allow glaze suspensions to dry rapidly on the biscuit wares. Firing temperatures to about 1,000°C were also common in China for northern glazed tomb-pottery, where everyday strength was not important.[213] 1,000°C seems also to have been a typical firing temperature for later Chinese Neolithic wares, though fired strength in this case was often boosted by reduction-firing. This turned the wares grey, but also created ferrous (iron II) ions within the ceramic bodies. The (iron (II)) ions served as useful fluxes by combining with free silica and raising fired-strength through the creation of iron-silicate body-glasses.

[212] A good account of 'dry' sintering may be found Singer & Singer (1963), pp. 171–3. The process of 'wet' sintering (sintering with a reactive liquid) is explained in Kingery (1960), pp. 386–9. Kingery notes: 'Here we are referring to systems where the solid phase shows a certain limited solubility in the liquid at the sintering temperature; the essential part of the sintering process is the solution and reprecipitation of solids to give increased grain size and density.' *Ibid.*, p. 386.

[213] This is the case for both Han and Thang dynasty tomb wares.

From about 1,100°C upward a further change occurs in the fired clay material as the spinel converts to mullite. More secondary silica is freed by this reaction, which in turn boosts the levels of body-glass, if sufficient fluxes are present to dissolve it:

$$3(2Al_2O_3 \cdot 3SiO_2)\ \text{(spinel)} + \text{heat} \rightarrow 2(3Al_2O_3 \cdot 2SiO_2)\ \text{(mullite)} + 5SiO_2\ \text{(silica)}\ (1{,}100\text{–}1{,}400°C)$$

The creation of mullite is the final stage in the thermal breakdown of the kaolinite crystal. It differs from the earlier stages in the way that the needle-shaped mullite crystals grow in all directions from the platy relicts of the original clay particles. These new fibrous crystals have strong reinforcing effects on fired clays, and enhance to a high degree the ceramic strengths already developed from sintering, and from the development of body-glass. Also, the longer that kiln-firings continue above 1,100°C, the larger and longer the mullite crystals grow, and the stronger the wares become. The presence or absence of mullite in fired clay is one of the clearest differences between earthenwares and high-fired materials such as stoneware and porcelain. It is the reinforcing effects of mullite, combined with abundant body-glass, that account for the superior strengths of both stonewares and porcelains.

One final feature of this high-temperature stage in firing is the thermal creation of a new form of silica: beta-cristobolite. Only small amounts of β-cristobolite are formed from available free silica but the material has a profound effect on glaze-fit as β-cristobolite undergoes a sharp contraction to its alpha form at about 226°C, almost at the last stage of cooling. This causes a minute shrinkage in the ceramic body itself. Glazes are solid by this time so the 'cristobolite squeeze' tends to put the glaze-coat into compression. This effect can prevent crazing completely, which in turn has a very beneficial influence on fired strength. Long firings at high temperature can also cause good reaction-zones to develop between glazes and bodies, and this too can limit or control crazing. This latter effect is offset to some degree by dissolution of some cristobolite into the body-glass during the long 'soaking' period, and silica in this glassy form shows much lower contraction on cooling.

Firing of Clays in North and South China

It can be seen from our discussion that a northern clay that entered the kiln in a dry state as a mechanical mixture of kaolinite, quartz and mica particles, can transform in a high-temperature firing to an inter-grown and bonded mixture of quartz grains, glass and mullite. Some cristobolite might also form, and this has a beneficial effect on glaze-fit. Most of the reactions described above concern changes that occur to the kaolinite crystal with increasing heat. This has particular relevance to north China because most northern stoneware clays contain from about 50–85% of kaolinitic minerals by weight. Southern stoneware clays, by contrast, may have as little as 10–20% kaolinite, and consist mainly of fine quartz and potassium mica, typically in 3:2 ratios. Potassium mica has a rather different thermal behaviour from kaolinite: it loses its chemically combined water nearer to 900°C and, because of its

potassium oxide content, converts to mullite, corundum (pure alumina) and glass, rather than to mixtures of mullite and silica.[214] Thus southern clays tend to show 'sugary' fractures after firing, caused both by their high quartz contents, and their greater amounts of body-glass. Although they lack the reinforcing effects of extensive mullite development, these quartz-rich, glass-bonded southern clays can still be very strong. Because of these fundamental differences in mineralogy south Chinese clays benefit from quick firings and quick coolings to temperatures at the lower end of the stoneware range. Too long a soak, or too high a firing temperature, may cause the southern ceramic materials to soften and collapse in the kilns.

These observations apply as much to typical south Chinese porcelains (such as early Ching-te-chen, Lung-chhüan and Te-hua wares, see pp. 357–9) as they do to southern stonewares. However, the deliberate addition of porcelain clay (kaolin) to porcelain stone at Ching-te-chen, particularly in the +17th to +20th centuries, produced a new style of clay-rich southern body in which fired strength was boosted by the formation of extra mullite. High kaolin bodies from Ching-te-chen can be regarded as falling between the typical southern and northern types. They could stand higher temperatures and longer firings than ordinary southern porcelains, though their overall shrinkages in firing tended to be rather high, due to the substantial levels of body-glass generated during firing.

FUEL

All the changes described above need substantial inputs of energy to occur. The high-temperature reactions that lead to mullite formation are the most demanding of fuel-use and kiln efficiency. However, the temperatures over which stoneware and porcelain are fired (typically 1,150–1,400°C) are also associated with substantial losses of heat. The heat escapes into the atmosphere, into the kiln's structure and into the kiln's setting materials, such as saggers, setters, shelves and props. Consequently only small amounts of the fuel used for firing intermittent kilns to high temperature are usefully employed in a firing the wares, as the following estimates show:[215]

Heating ware, saggers and supports = 10–12%
Heat taken by the kiln's structure = 30–40%
Heat lost by radiation from kiln walls and conduction to ground = 20–30%
Heat lost in waste gases = 20–30%

Saggers and setters may have at least four times the mass of the wares they contain and support, and this further reduces firing efficiency. As a result only 2–4% of the fuel actually burned in a firing may be actively involved in firing the wares, making

[214] Sundius & Steger (1963), p. 385.
[215] Rosenthal (1949), p. 107. Intermittent kilns are those where the heat is raised to fire the wares, and then the kilns are allowed to cool and the wares unpacked. With modern continuous kilns the wares pass slowly through the heated chamber in the centre of a tunnel, which remains at a constant temperature.

high-temperature ceramics particularly prodigal in their use of fuel. This is apparent when the fuel consumption of the saggers and the ware are considered separately:[216]

Heat used for firing the ware = 2–4%
Heat lost in brickwork and through radiation = 36–44%
Heat lost in saggers (weighing about five times their total contents) = 10–8%
Waste gases = 52%–44%

SOURCES OF ENERGY IN FIRING HISTORICAL CERAMICS

It is not too far-fetched to claim that all historical ceramics have been fired by solar energy, although only in the rarest cases has the sun's energy been used directly.[217] The more usual approach is the liberation of solar energy stored in organic fuels (mainly plant-straw, reeds, cereal-husk, wood, charcoal, peat or coal) through combustion in air. This neatly reverses the processes that created fuel in the first instance, i.e. the building up of complex organic molecules in plants' leaves through energy supplied by sunlight.

The main components for the dozens of complex hydrocarbons and carbohydrates that are present in plant material are water, drawn from the ground by the plant's roots, and carbon dioxide from the air, taken in through the undersides of the plant's leaves. The energy needed to construct such long-chain molecules as cellulose and lignin comes from sunlight absorbed by the leaves' upper surfaces, and the by-products of this biological synthesis are surplus water and oxygen. During clean combustion (burning) these complex organic molecules break down once more to carbon dioxide and water, the energy used to construct them is freed as heat and light, and any incombustible materials are left as ash.[218]

STAGES IN BURNING

Glowing combustion

Solid fuels will not burn direct, they must first be roasted, through 'pyrolitic cracking', to release their volatiles. Some of the energy gained from the burning of these volatiles roasts more fuel, which sustains and extends the reaction. In the case of wood about half the potential energy comes from the burning of the volatiles driven from the fuel, and about half from the burning (oxidation) of the remaining 'char'

[216] Singer & Singer (1963), p. 971, table 223.

[217] A rare case of the direct utilisation of solar power was Von Tschirnhaus's experiments with ceramic raw materials in Saxony, see pp. 749–50.

[218] Hemicelluloses contain chemically combined water and their compositions have been given as $[C_6(H_2O)_5]n$ or $[C_5(H_2O)_4]n$. Lignin has the approximate composition of $C_{10}H_{11}O_3$; see Shafizadeh (1981), p. 107, for a detailed account of their combustion. Wood ash consists largely of incombustible materials such as silica, and elements, such as calcium, magnesium and potassium, mainly in carbonate form.

(charcoal). The burning of char is known as glowing combustion while the volatiles burn with flaming combustion. Although char is not wholly carbon (its formula is nearer to $C_{67}H_3O$) its combustion can be represented by two stages, glowing combustion and full burning.

As air enters the firebox, either under or in front of the fuel, vigorous oxidation occurs where air meets the burning fuel. This is the glowing combustion of char in air containing 20% oxygen. It can be summarised as $C + O_2 \rightarrow CO_2$, a reaction that liberates the considerable energy of 14,000 units of heat per pound of carbon. As the incandescent carbon dioxide rises through the glowing char some CO_2 is reduced by the red-hot carbon to carbon monoxide ($CO_2 + C \rightarrow 2CO$). This absorbs energy of 6,000 units lb/C. However, at the surface of the fuel the hot carbon monoxide burns in air passing over the fuel, again providing energy, of 10,000 units per lb. This reaction, $2CO + O_2 \rightarrow 2CO$, gives a flickering blue flame. Particulate carbon (soot) may also form in the combustion gases from the breakdown of carbon monoxide in the following reversible reaction: $2CO \Leftrightarrow CO_2 + C$. Thus the burning of char may give carbon dioxide, carbon monoxide or soot. The balance of the three products depends largely on ambient burning temperatures and on the amounts of air admitted above and below the mass of fuel.

Flaming combustion

As wood is 'cracked' by exposure to glowing combustion, a mixture of tar droplets and volatiles is carried from the fuel by the fire's draught. These burn fiercely above the fuel, in the firebox, in the kiln-chamber and, sometimes, both in and above the kiln's chimney. The tars are mixtures of levoglucosan, anhydrides and oligosaccarides, while the volatiles tend to be a variety of carbonyl compounds such as acetaldehyde, glyoxal and acrolein.[219] These chemicals tend to be supplied by the breakdown of the cellulose components of the fuel, leaving the lignin to make the char.

Given the complexities of these compounds, 'flaming combustion' is hard to model. Nonetheless some image of the reactions involved comes from the burning of the simple hydrocarbon, methane (CH_4). For example, in ample air methane will burn with the following energy-producing reaction: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$. If the oxygen supply to the burning fuel is restricted somewhat, carbon monoxide, carbon dioxide and steam will be produced from the methane: $3CH_4 + 5O_2 \rightarrow CO + CO_2 + H_2O$. And, if the air supply to the fuel is restricted further still, particulate carbon (soot) and steam will appear in the kiln-chamber: $CH_4 + O_2 \rightarrow C + 2H_2O$.[220]

If enough air is allowed to burn the wood (particularly the 'secondary' air admitted to the firebox above the burning fuel) both CO and C will burn throughout the firebox and kiln-chamber, with the reactions described for char. If air is restricted

[219] Shafizadeh (1981), p. 107.

[220] These effects appear successively when the air-valve on a Bunsen burner using natural gas is gradually closed.

somewhat a reducing atmosphere will prevail in the kiln. If the fuel is seriously starved of air, particulate carbon (black smoke) will fill the kiln-chamber and the fire will begin to fail. The results of deliberate manipulation of air supply are plain to see in Chinese Neolithic wares, which may be red or yellow-buff from oxidation, grey from reduction, or black where the clays have been intentionally carbonised with excess smoke. There is also a tendency for most solid fuel firings to pass regularly through these smoky → reducing → neutral → oxidising phases, as fuel is added to the kiln's firebox and it burns away. Such cycles will tend to give oxidising-to-neutral results overall, and deliberate restriction of air is usually needed if grey and black wares are being made.

Different Solid Fuels

Fuels can be usefully classified by their balances of carbon to volatiles, and this effectively separates materials such as wood, peat, lignite, coal and anthracite. This balance also helps to explain their varying usefulness for kiln-firing, with the longer-flamed volatile-rich fuels being the more useful. Peat itself is simply woody or plant material, saved from bacterial digestion by accumulation in dark and acid conditions in boggy water. Overlays of silts eventually form sedimentary rocks such as shales, sandstones and limestones. These rocks provide pressure that removes water and converts the peat to brown coal or lignite, a process accompanied by some organic decomposition. Bituminous coal is the natural end-product of this effect. True anthracite needs further heat and pressure to form, thus condensing the material further still and driving away most of the remaining volatiles.

The earlier stage of this process – the lignite-to-bituminous coal transition – has been described as 'partly bacterial and partly chemical', with the following equation proposed for its operation:[221]

$$\underset{\text{Lignite}}{C_{57}H_{56}O_{10}} \rightarrow \underset{\text{bituminous coal}}{C_{54}H_{42}O_5} + \underset{\text{water carbon dioxide}}{3H_2O + CO_2} + \underset{\text{methane}}{2CH_4}$$

The differences between these various fuels are shown graphically in Fig. 10.

As the series moves towards anthracite, the eight fuels become increasingly compact sources of energy, though the flames they provide in burning become progressively shorter as their volatile proportions diminish, causing glowing combustion gradually to replace the flaming type.

Fuels in China

It may be noticed that the above discussion has concentrated on wood and coal, which are the two prime fuels used for firing historical Chinese ceramics. Many modern kilns in China tend to use gas, and occasionally oil, in firing. It may seem

[221] Tiratsoo (1967), p. 51.

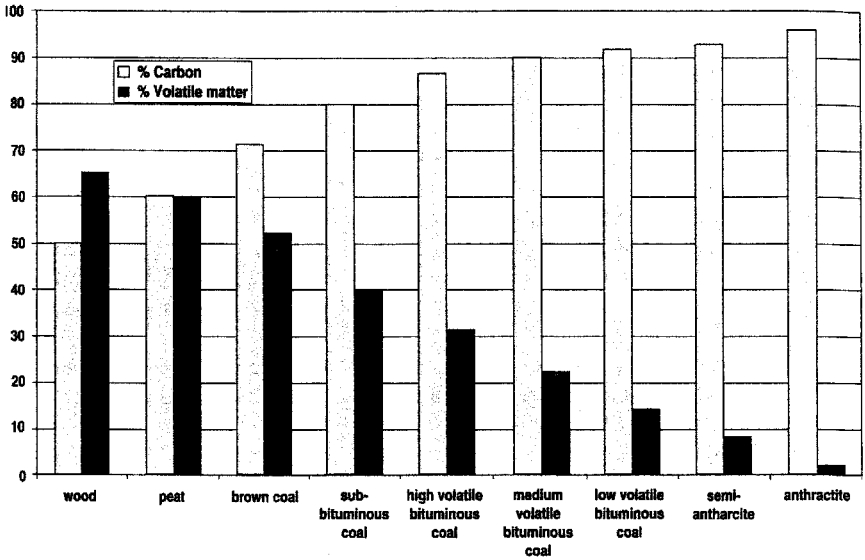


Fig. 10 Balances of volatiles to carbon in solid fuels

superfluous to note that there is no evidence at present for oil or gas having been used for firing early Chinese kilns. Nonetheless there is a suspicion that crude oil was used to fire some Neolithic Mesopotamian kilns in the -2^{nd} millennium.[222] In China natural gas was certainly drilled for, and piped, in Han times, and then burned beneath great cast-iron dishes for evaporating brine. There is no evidence that natural gas (mainly methane) was ever used for firing ceramics in ancient China, probably because the volumes needed would have been more than the wells could have supplied, and the status of ceramics too low for the investment involved. Another fuel that was little used in China for firing kilns, although it is widely exploited elsewhere in the world, is herbivore dung. Dung as a fuel for firing ceramics tends to be associated with pastoral cultures and with a shortage of wood. It is an efficient fuel, and is particularly suited to bonfire-firing techniques, where fuel and ceramics are in direct contact.[223]

[222] Van As & Jacobs (1991), p. 541. The authors make a good circumstantial case for the use of crude oil for firing some Neolithic ceramics in Iraq, and note that crude petroleum was used in oil lamps of the -2^{nd} millennium in the region. They also describe modern practice in a traditional pottery north-east of Baghdad: 'The crude oil, poured into a hole in front of the firing chamber, was continuously scooped from the pit into the fire with help of a bowl or soup ladle . . . The result was a roaring fire, filling the wide low chamber, more than three metres in section.'

[223] Sillar (2000), p. 46, reviews dung's use for firing ceramics in India, Pakistan, Africa and North and South America and notes: 'cows, sheep and llamas drop about four times their body weight in dried dung each year, turning widely dispersed and bulky grasses into a compact and easily gathered source of energy and nutrients.'

KILNS

Combustion theory and an understanding of the natures and stages of ceramic change, and the dangers from such effects as steam explosion and quartz cracking, can make Chinese kiln designs far easier to interpret. Heat has to be introduced to these structures initially as a mere trickle, and then gradual built to a torrent. Insulation has to be effective if fuel is not to be wasted, and cooling must not happen too fast if the wares are not to crack. There are numerous ways to satisfy these criteria, with perhaps the least likely being no kiln at all. All stages in the development of Chinese kilns will be further explored in Part 3 of this book.

USING CLAYS TO FORM POTS

Clays must be manipulated into forms before they can be fired to become ceramics, and the wealth of manufacturing methods and sequences used in China are examined in Part 4. Here some essential principles of clay working are introduced.

WORKING WITH PLASTIC CLAY

It is a general instinct, when given a piece of clay, to press and model it into some kind of shape. The clay responds to pressure, and it retains its new form when distorted. Clay cannot be worked indefinitely, however, as it soon begins to dry with the heat of the hands and from draughts in the air, and may even begin to crack at the edges with further work. As it dries it also becomes progressively harder to manipulate. Once completely dry clay has some strength, but a light knock can easily break it.

These familiar stages in the handling of clay are fundamental to the making of ceramics. The plasticity comes from ensuring that enough water is present in the mixture to lubricate the fine platy clay particles, so that they can slide under pressure and form new arrangements that are preserved by surface tension. As the clay begins to dry many mineral-grains come into direct contact and are far less mobile, increasing the force that is needed to distort the form. With further drying the clay soon reaches a point where its shape can no longer be changed by pressure, but only by cutting, abrading or carving.[224]

Thus the main form of a coil pot might initially be made with relatively soft clay with about 20% water by weight. When stiffened somewhat (perhaps to about 15% water) it might be beaten, using the 'paddle and anvil' method to refine its shape and to consolidate the material.[225] Beating tends to restore some mobility to the

[224] See Rosenthal (1949), pp. 62–5, for a good account of the nature of clay. Also Lawrence & West (1982), pp. 71–81.

[225] In this technique the paddle (usually wood) is used outside and the anvil (usually a pebble or fired clay dome, but sometimes just the hand) is held inside. The anvil supports the clay as it is beaten, thinning and compressing the material at the same time as the form is refined and enlarged. Clay-beating paddles are often textured or cord-bound. This seems to discourage the paddles from sticking and also decorates the vessels at the same time as their shapes are formed.

clay, at the point where it is beaten, a process akin to tapping firm wet sand. At about 10% water the clay is very stiff, but can still be scraped smooth. And at about 5% water, just before it dries, the clay can be burnished by rubbing with a hard smooth tool. Each of these making and finishing stages would only be attempted when the potter judged that the water content was suitable for the next process: usually by letting the objects dry evenly in a controlled environment.

With thrown wares the pattern is similar. The clay would be used in its plastic state on the wheel and then dried carefully to its 'leatherhard' state. The thrown vessels could then be returned to the wheel and upended. Excess clay could then be pared away from the spinning vessels with cutting tools made from metal or bamboo – a process known as 'turning' – after which the forms could have any necessary sprigs, handles or spouts applied.[226] They would then be allowed to dry completely, probably with some final cleaning or fettling before they were set in the kiln for firing. In short, as plastic clay gradually dries out it becomes progressively harder to form by pressure and soon reaches a stage where 'subtraction' has to replace distortion as the main method of manufacture.

THROWING

The process of throwing (often called 'turning' in North America) is fascinating to watch, even for an experienced potter. For the speed and precision of its operation, using a soft and plastic material, it matches glass-blowing as a paradigm of the 'workmanship of risk', where production is rapid, but everything can be ruined by a single false move.[227] Throwing may take years to master, and a high level of skill to execute efficiently. Sureness and strength are needed at the start of the process (centring and opening) and the lightest of touches during the finishing stages where the final form is achieved.

In practice, the potter throws a ball of clay on to the centre of the wheel-head, and immediately applies water, and then firm pressure, to make it run true. Once centred the clay is opened, again by pressure, to make a well in its centre. The thick-walled vessel is then progressively thinned by pressure, usually with one hand inside and the other outside, which causes the walls to rise and the pot's volume to enlarge. The rim is regularly steadied and compressed as making proceeds. Water or slip is applied to the spinning clay to reduce friction from the hands otherwise the soft and spinning vessel might buckle and collapse. Although it is not apparent to the viewer (or even to the thrower), the clay particles in a pot's wall may be dragged round in a spiral in as many as three complete turns by friction from the potter's fingers.[228]

[226] If spouts and handles are set high on the form they may be attached before, rather than after, turning (turning often only removes the thicker clay towards the vessel's base).

[227] The term 'workmanship of risk' was coined by the scholar and furniture-maker David Pye. See Pye (1968), p. 17, for a discussion of the concept.

[228] This spiral travel can also continue during firing as the vessel continues to twist slightly in a direction counter to the original spin of the wheel, still being affected by the original drag that was applied in making. See Cardew (1969), p. 122, for a fuller discussion of the effect.

The principle of pressure has been stressed in this brief description of throwing because to the observer it appears as if the clay were being pulled up by the potter's hands, and then pushed out to make the volume of the vessel.[229] This illusion is underlined by the potter's tendency to talk in terms of 'pulls' and 'lifts' for the early stages of manufacture. In practice, throwing, like virtually all ceramic-forming methods, is a wholly compressive process, with the clay moving upwards as the thrower compresses the moving clay between his or her hands. In most ceramic-making methods the movement of clay tends to be 90° to the direction the pressure is applied, but the spin of the potter's wheel makes this closer to 45° in the case of throwing. Nonetheless the *apparent* movement of the clay is directly upwards. The smallness of the clay crystals, and the material's very low elasticity make this compressive approach essential.

Another subtle process that can operate in throwing is the increased mobility of the clay particles where they receive pressure from the thrower's hands. Plastic clay tends to 'set' somewhat when undisturbed, but becomes more mobile on agitation, a thixotropic phenomenon that is also exploited in the beating of half-finished hand-built vessels.

Removing the Vessel

During throwing the vessel is necessarily firmly fixed to the wheel-head, by exploiting the natural stickiness of clay. It therefore needs to be cut off when the shape is finished by using thin string, a wire or less often, a fine blade. A variant on this theme, sometimes used in China and in other countries of East Asia, is where a dusted circle is made on the wheel-head by sprinkling sand or ash, within a temporary bamboo ring. The ball of clay is then dropped on to this dust, overlapping it slightly so the clay is attached only at its outer edge. When the vessel is finished it is released from the wheel-head by a slight undercut of the clay at its foot. This allows the vessel to be easily lifted off.[230]

[229] The term 'throwing' may refer to the way that a potter throws a ball of clay on to the centre of the wheel head in order to make it stick securely, prior to making. A fast thrower may take only 20 seconds to make a pot, so an observer may see the potter throw a lump of clay on to the wheel three times in a minute. Alternatively it may derive from the Old English *thrāwan* 'twist, turn' from West Germanic (Thompson (1995), p. 1454), although the sense here is to writhe rather than to rotate. Yet another explanation refers to the 'throw' of the spinning clay. However this seems connected with an erroneous belief that centrifugal force is essential to the process of throwing, i.e. that the potter exploits this force in some way in order to make the technique work. See Singer *et al.* (1954), p. 203; Rice (1987), p. 133; Orton *et al.* (1993), p. 117; and Gibson & Woods (1990), p. 279. It is taken to follow from this that the throwing wheel must reach a good speed in order to generate a useful amount of 'throw' (centrifugal force) and this differentiates the use of the 'slow wheel' from the 'fast wheel'. Throwing is certainly facilitated to some extent by the wheel's speed, but only so that the hands have to be kept less rigid, and the work proceeds faster. The innate stiffness of clay makes centrifugal force a secondary effect in throwing, and the process would still work well if the effect were absent. While it is true that centrifugal force makes it easier to bring a thrown shape out than to make it go in, it is not actually making the process possible. It is also true that when wide bowls are allowed to spin too fast on the wheel at the last stage of making, they will sometimes flare, and crack at their rims. However, gradual slowing of the wheel is practised by most throwers as the forms near completion, so the problem rarely occurs.

[230] Laufer (1917), p. 164. Chinese potters use similar methods in present-day Thailand, pers. comm. with the Singapore potter Peter M. Lau.

Another popular Chinese technique is to throw smaller vessels and bowls from the top of a large 'hump' of clay, which has the extra advantage of increasing the mass and the momentum of the wheel. In this case the vessel may be cut off with a pointed tool or a short thread, or simply nipped off by thumb and fingers while the wheel is spinning. In most cases this means that the vessel needs more extensive finishing at its foot by turning than would be the case were it made direct on the wheel-head.

Relatively soft clay is used in throwing, and the clay becomes softer still from the water or slip used in the manufacturing sequence; it is also possible to make the pot's walls very thin with this technique. All this means that a thrown pot may be difficult to remove from the wheel-head without distortion, and various strategies have been evolved by potters to cope with this problem. Perhaps the most popular method in China is to leave substantial clay at the vessel's foot, and to grasp and lift it at this point. The object may go oval as it is raised, but resumes its shape when set down on a level surface. Small bowls may be cupped in the hands as they are lifted from the wheel, and larger vessels carefully picked up from below the fullness of their forms.

In the +18th century, the efficiency of throwing at Ching-te-chen was well described by Père d'Entrecolles, and in the +20th century was illustrated by Archibald Brankston and recorded on film by the Ching-te-chen potter Li Chien-Sheng 李健生 (see also pp. 445–6).[231]

TURNING[232]

Turning is a subtractive process that cannot begin until the clay is at least leather-hard.[233] In the simplest form of finishing, a leatherhard pot can be held in one hand, or placed in the lap, and excess clay scraped away with an edged tool. Diagonal freehand scraping of this type is often seen on Yang-shao Neolithic wares, especially towards their feet.[234] The process can be speeded greatly, however, by returning the wares to the wheel, securing the vessels or covers upside-down, and then turning away excess clay in a manner reminiscent of wood-turning although, in practice, clay offers much less resistance than wood to the cutting-blade. Turning is usually employed to finish the feet of vessels, to form foot-rings, and also to complete lids and covers. In Chinese porcelain manufacture, turning is often applied to the entire porcelain forms, both inside and out, in order to provide the most accurate profiles and sections possible. Southern porcelains (unlike northern stoneware clays) are

[231] Brankston (1938), pp. 60–8, pls. 36–8; Li Chien-Sheng (1996), video-film.

[232] In North America 'turning' is often called 'trimming' as the term 'turning' is also used there to mean throwing.

[233] The term 'leatherhard', used widely in the pottery industry, may seem an odd one, but it probably derives from the English country pottery tradition, where local earthenware clays tended to become unusually tough and leathery in their half-dry states, feeling like old leather flagons or leather buckets. The term was carried over into the north Staffordshire pottery industry, although the clay-poor prepared bodies eventually developed for making white earthenware and bone china in Stoke-on-Trent were less obviously leathery at this stage of drying.

[234] Vandiver (1988), p. 157.



Figs. 11–18 Potter at Yao-chou throwing off top of hump of clay Fig. 11



Fig. 12

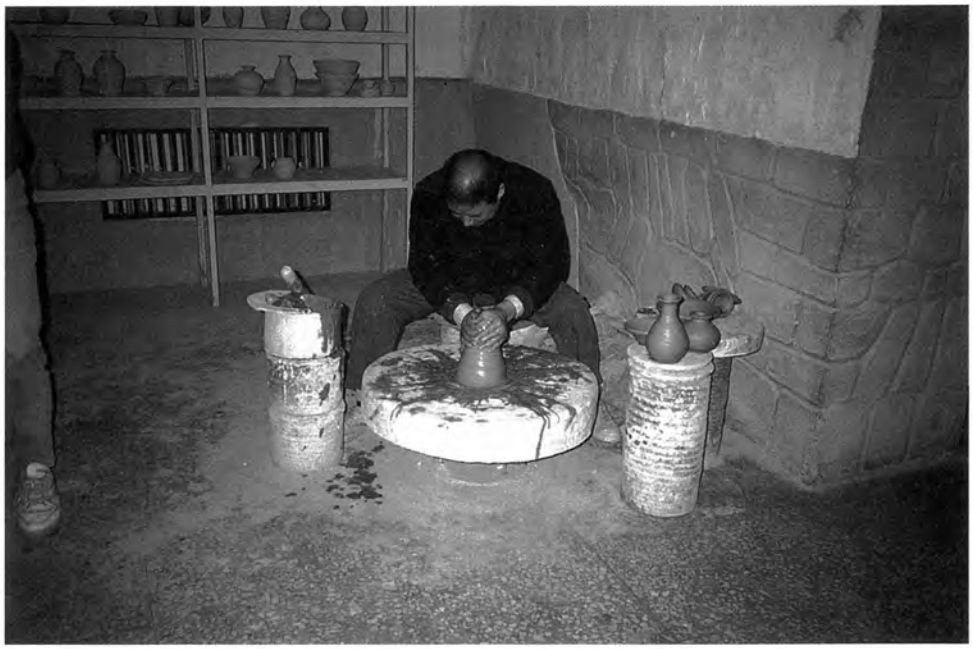


Fig. 13



Fig. 14



Fig. 15

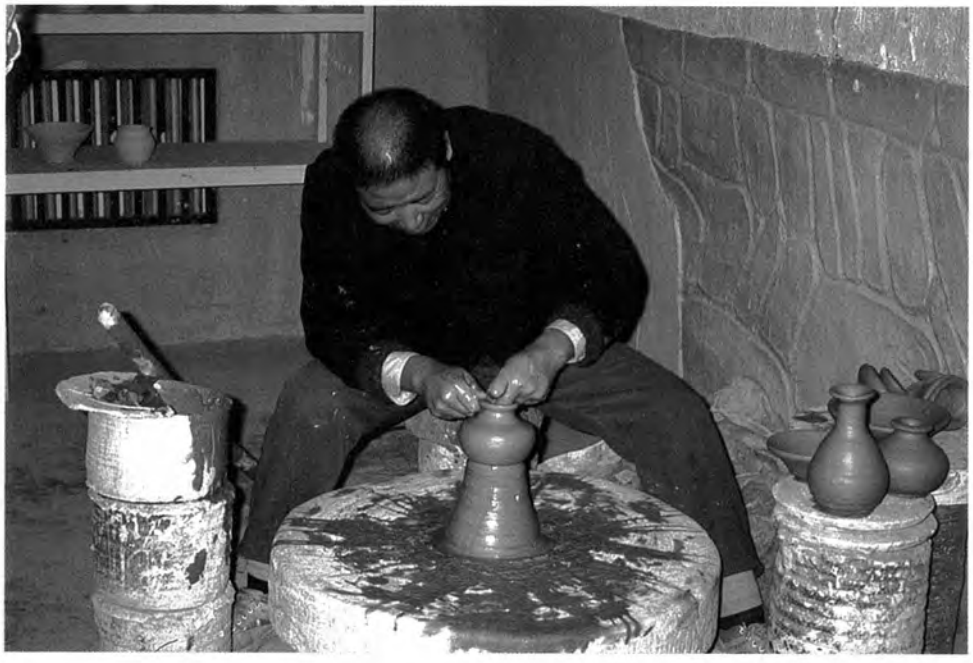


Fig. 16



Fig. 17



Fig. 18

often turned when nearly dry as the silty porcelain materials lend themselves to this treatment.[235] It is also possible to burnish wares while they are still on the wheel, after turning, simply by holding a smooth hard instrument against the spinning clay.

Thien Kung Khai Wu (+1637) gave a historical record of various turning practices, after initial throwing of vessels, including truing on a plain mould. The potter's wheel revolved round a wooden axle planted into the earth to a depth of 3 feet to make it stable, with an exposed portion 2 feet high. The vertical axle was mounted with a horizontal disc or turntable, which was set in motion by applying a short bamboo stave to the outside edge. A 'helmet' (i.e. a domed supporting mould) protruded from the centre of the turntable and in making ordinary cups and dishes clay was pressed over the mould. Then the potter shaped the clay body as the turntable revolved, pressing his thumbs (with clipped nails) into the base of the clay and running them upwards. Cups and bowls were made like this, and apprentices were allowed to set aside their spoiled items and try again with fresh clay. After long experience, when the potter was very skilled, every piece off the wheel was identical, as if it had come out of an identical mould. If medium dishes or large bowls were made, more clay was added and used after it had dried slightly. After the first turning, vessels were pressed on to the mould a second time, then air-dried for a short time, then pressed again while the clay still retained some moisture. When the piece was completely dry, as indicated by its pale white colour, it was dipped once in water and mounted over the mould again to be trimmed with a sharp blade; while this was going on the slightest tremor of the hand resulted in slight nicks in the porcelain body made by a juddering turning tool. Then the piece was inspected and blemishes touched up.[236]

MOULDING

Some of the first entirely moulded ceramics made in China were made in the late Bronze Age, and they appear to have been made by pressing thin slabs of clay, or by smearing soft clay, into hollow moulds (see pp. 405–7). Moulded vessels are legion in Han dynasty burial wares, and reappear in quantity among lead-glazed wares of the Thang dynasty. Thereafter, moulding became the second most popular technique to throwing at most Chinese kilns sites for hundreds of years. After clay slabs or plastic clay were pressed into open moulds, they naturally released themselves from the moulds as they shrank in drying. Often moulded sections were joined when leather-hard to make closed vessels. The inevitable consequence of this technique is that

[235] Observed and photographed by the authors at Ching-te-chen in +1982. Long narrow curved blades made from iron were used to turn the insides of vases. Finely toothed blades were used for the initial turning (for rapid cutting and to avoid 'chattering') with plain-bladed tools used for finishing.

[236] *Thien Kung Khai Wu*, ch. 7, pp. 6b–7a. Sun & Sun (1966), pp. 147–8.

the moulded objects had one good side (from the mould face) and a rougher side from where the clay was pressed into the mould.

Much rarer in Chinese ceramic history are wares that were made by squeezing clay between *two* moulds, to give fine moulded surfaces on both inner and outer faces. The technique seems to have been first used on any scale with moulded Chün ware 鈞窯 flowerpots at the Yü-hsien kilns 禹縣窯 in Honan province (see pp. 441-2).

A Reflection on Glazes

As important as the physical properties of ceramic materials, and their shaping and firing, are the decorative treatments applied to their surfaces. Ceramics can be decorated after firing, but such designs are impermanent. The rare use of cold decoration in China will be explored in Part 6 of this book. Durability and impermeability are best achieved with the application of a fired surface coating, or glaze. China has the richest tradition of ceramic-glazing in the world, and as a preamble to its investigation we shall consider the nature and appearance of glazes, which are further discussed in Part 5.

As is well known, our sense of the material world is rather superficial, relying as it does largely on light reflected from the surfaces of objects. However solid or substantial these objects may be in reality we can only see the top few microns of their structures, and it is from these impressions that we have learned to make assumptions about what is beneath. As the surfaces of objects are so important to human perception, any changes made to them can transform our sense of the objects concerned.

Ceramics provide a good illustration of this principle, with the bonus that improvements of ceramic surfaces often combine utility with beauty. For example, the burnishing that is seen on much Chinese Neolithic earthenware was managed by rubbing the half-dry clay with a hard smooth instrument to align and flatten the platy clay particles. Burnishing also helped to reduce crack-propagation, making the fired objects stronger and easier to clean. Besides these practical advantages burnishing also enhanced the appearance of the vessels, often creating the illusion of a finer material. The thin coats of glass that can be fused on to ceramics during firing serve similar functions. Ceramic glazes can increase the fired strength of an object substantially (both structurally and superficially) as well as making it more practical to use. At the same time, ceramic glazes have always been appreciated for the ways that they can transform both the colours and the tactile qualities of the objects that they cover.

In terms of perception, ceramic glazes can also show some unusual features. Our sense of a glazed ceramic comes mainly from its outer surface, but we can also be conscious of the material beneath the glaze, i.e. the fired clay itself. In this case we may be seeing a millimetre or so through the transparent glassy coating to the

ceramic body – a rare example of both transmitted and reflected light being involved in the visual appreciation of an object.

As well as showing transparency, ceramic glazes may also be translucent, an effect caused by some scattering of light within the glaze's thickness. This prevents the clay body from being illuminated effectively, but there is still a sense of something present beneath the glaze. The translucency of glazes is related to materials such as polished jade, where light penetrates some distance into an object to give a smooth, subtle and semi-luminous quality that is quite different from the flat appearances presented by most objects in the material world.

Ordinary transparent glazes, through which the fired clay is visible, are perhaps the most familiar types in world ceramic traditions. But it is for the use of thick translucent glazes with complex microstructures that Chinese ceramics are particularly famous. The best examples date from the +11th to +14th centuries, when they were often used on grey stoneware clays. With these wares the stoneware material can be dimly sensed beneath thick glazes, adding a further dimension to the glazes' qualities. The aesthetic potentials from such effects were exploited on such famous imperial wares as Chün ware, Kuan ware 官窯, Ko ware 哥窯 and Ju ware 汝窯, all made during the Sung dynasty and further discussed on pp. 574–7, 595–600, 604–6. Those ceramics still stand at the zenith of Chinese glaze technology.[237]

Although glazes of this thick and translucent style were not achieved until glaze-making reached a sufficient level of development in China, an appreciation for similar visual quality is implicit in Chinese material culture as early as the Neolithic period, most notably in the carving and polishing of jade and other hardstones. The laborious forming and finishing processes, necessary with hardstone working, revealed the innate qualities of the materials, and also realised their tactile potentials. With Chinese glazes too, it is through touch as well as sight that many fine glazes have been appreciated.

The Nature of Glass and Glaze

In terms of composition and physical behaviour the differences between glasses and glazes are small, and mainly concern raised viscosities and reduced expansivities in glazes, compared with most glasses. The first effect helps prevent glazes from running at maximum temperatures, while reduced expansivities help match the expansions and contractions of glazes to the ceramic materials beneath. Even these precautions were sometimes unnecessary, as seen in the majority of Near Eastern glazes, which tended to be made from crushed soda-lime glasses. A combination of high-expansion clays and careful firing allowed potters in West Asia to use ordinary glass as their main glaze constituents, with only minor additions of clay and/or gum.

[237] Chen Xianqiu *et al.* (1986b), pp. 161–9; Guo Yanyi & Li Guozhen (1986b), pp. 153–60.

GLASS THEORY

All historical glasses and glazes world-wide are based on the oxide of silicon (silicon dioxide or silica) the most abundant oxide in the earth's crust. Silica accounts for some 59% by weight of the top ten miles of the earth's surface and, in a nearly pure form, is found in enormous quantities in such common materials such as sand, quartzite, sandstone and flint. Typical igneous rocks, clays and porcelain stones contain from about 45 to 75% silicon dioxide by weight, so these common materials can also serve as useful and abundant sources of silica.

The element silicon is described as a metalloid and shares with four of the more abundant elements in the periodic table the capacity to form a glass after melting in its oxide state. Other glass-forming elements are phosphorus, germanium, boron and arsenic, all of which provide oxides that have the unusual capacity to cool without crystallising.[238] Most other elements and compounds produce masses of micro-crystals at their freezing points, and the flat faces between these crystals, known as grain-boundaries, tend to reflect light and consequently make the materials opaque to the naked eye. Nonetheless, if these crystals are cut across their thicknesses, many opaque materials can be rendered transparent, and that phenomenon is exploited particularly in the thin-section microscopy of rocks.[239]

The disinclination of glass-forming oxides to crystallise tends to leave their atoms in a random network arrangement when the materials solidify. This state is not quite so random as found in liquids but it is still very different from the orderly patterns of atoms seen in crystalline materials, and now clearly revealed by such powerful modern techniques as tunnelling electron microscopy (see pp. 785–6 for further discussion of this technique).[240] The lack of grain-boundaries in glass means that, although a small amount of light is reflected from the front and back surfaces of glassy solids, most light passes through the material, making it possible to see materials or objects beyond. In the case of transparent glazes the materials visible beyond the glassy coatings are the ceramic bodies themselves.

Even with potentially glassy materials, extremely slow cooling may eventually produce a true crystalline structure. For example, a volcanic glass (obsidian) may have a composition identical to granite, but rapid surface cooling of the original magma has created a glassy material, while slow subterranean cooling can render the same magma coarsely crystalline and granitic. Glazes too are sensitive to cooling rates: rapid cooling may give an entirely transparent glaze, while slow cooling may create in the same composition a matt surface and a thickness packed with micro-crystals. In some cases even true glasses can eventually crystallise ('devitrify')

[238] Anon. (1988), p. 2.

[239] A typical thickness of rock for thin-section microscopy is 0.03 millimetres. See Orton *et al.* (1993), pp. 140–1.

[240] See Brill (1962) for a good introduction to the nature of glass. Kingery (1960), p. 143, distinguishes between fused silica and true super-cooled liquids, noting that: 'glasses such as fused silica are an extended three-dimensional structure built up from co-ordinated groups that have definite first co-ordination, but lack long-range periodicity . . . This kind of random network structure is the most important kind of non-crystalline solid and is found for oxide glasses, hydrogen bonded inorganic solids, and organic compounds containing hydroxide groups.'

some hundreds of years after their manufacture, particularly if their original compositions were seriously unbalanced. Similar effects may also occur in glazes, due to heavy weathering or to attack by groundwater, and these agents can render once-transparent glazes opaque and/or iridescent.[241]

The melting-point of silica is cited variously between 1,680°C and 1,713°C, which is a reflection of its rather sluggish melting under extreme heat. These temperatures are incandescent blue-white heats and are reached today mainly in electric-arc furnaces, used to manufacture materials such as the advanced ceramics described in Part 7 of this book. Ordinary quartz sand will melt and fuse at this temperature, but temperatures nearer to 1,800°C are needed to create liquid silica glass fluid enough to produce a material free from 'seeds' (fine bubbles). Once achieved, the physical properties of pure silica glasses are quite exceptional: they combine the hardness of quartz with almost zero expansivity. They can be heated to white heat and plunged into icy water without cracking, and they also show unusual optical properties, such as very high transparency to ultra-violet light.[242]

The temperatures needed to melt silicon dioxide, however, are so high that pure silica glass is something of a technical curiosity, though the material may occur in nature where lightning has struck a sandy desert. Because of the huge amounts of energy involved in its preparation, fused silica glass is expensive to produce and confined to specialist use. More ordinary glasses exploit the principle of fluxes or 'network modifiers'. These are materials that can be added to silica, to lower its melting-point to temperatures manageable in simple kilns or glass furnaces.

FLUXES

Virtually any oxide added to silica will lower its melting-point, and give a glass or a glaze at a temperature lower than the melting-point of silica itself. Sometimes the effect is minor: for example, 5.5% of aluminium oxide can lower silica's melting-point to 1,545°C.[243] Sometimes the effect is major: for example, a mixture of 91.7% lead oxide with 8.3% silica will provide a glass that begins to melt at 552°C, which is a dull-red heat.[244] Additions of fluxes to silica tend to lower the hardness of the glass produced, and also to raise its expansivity. Such lowerings of the technical qualities of glass or glaze are most obvious in the case of earthenware glazes (i.e. those maturing below about 1,150°C). These need substantial additions of flux to melt the silica to glass and the resulting glazes are easily scratched, and may also have a strong tendency to craze.

[241] Wood *et al.* (1992), p. 133.

[242] Singer & Singer (1963), p. 309.

[243] Singer & Singer (1963), p. 402. Kingery (1960), p. 277, however, gives a slightly different version: 'The eutectic between mullite and cristobolite occurs at 1,595°C to give a liquid containing about 94% SiO_2.'

[244] Singer & German (1960), p. 86. Lawrence & West (1982), p. 10, summarise the phenomenon thus: 'Simply stated, the addition of these oxides increases the oxygen: silicon ratio above the 2:1 ratio present in pure silica glass [SiO_2]. As a result the silicon oxygen network becomes discontinuous, breaks, or weak points in the structure result, melting-points are reduced, viscosity is decreased and thermal expansion is increased.'

The fluxes that have proved to be the most important in the history of glass and ceramics are sodium oxide (Na_2O), potassium oxide (K_2O), lead oxide (PbO) and calcium oxide (calcia, CaO). Potassium, sodium and lead oxides can all be used in both low- and high-temperature glazes, although they are somewhat volatile in the stoneware range. Calcia is essentially a high-temperature network modifier and has served as the premier glaze-flux in most Chinese stoneware and porcelain traditions.

One curious aspect of silicate fluxes is that adding more flux to a glass or glaze recipe does not automatically lower its melting-point. There tends to be an optimum amount for any given flux and once this is exceeded the melting-point of the glass or glaze may actually rise. Another odd phenomenon is that some fluxes, such as calcium and magnesium oxides, have substantially higher melting-points than silica itself (CaO melts at 2,572°C and MgO at 2,800°C). But when these high-melting fluxes are added to silica, in the correct proportions, glasses with melting-points far below both that of silica and of the fluxes themselves may be produced. Examples of this phenomenon are the silica-calcia glasses created in Von Tschirnhaus' solar furnace in +1699, and mentioned on pp. 750–1.[245] Silica melts above 1,713°C, calcia at 2,572°C, but a 60/40 silica/calcia mixture will melt at 1,545°C. Perhaps more remarkable still, the addition of a third refractory ingredient to the silica-calcia glass (aluminium oxide, melting-point 2,050°C) can further lower its melting-point to 1,170°C. The oxide proportions in this particular glass or glaze are: silica 62%, alumina 14.75% and calcia 23.25%. This mixture represents the lowest melting combination in the silica-alumina-calcia 'system'.[246] A closely related low-melting mixture has the composition: silica 63%, alumina 14%, calcia 20.9%, magnesia 2.1%.[247] These latter two oxide mixtures have provided the chemical bases for the majority of Chinese, Japanese and Korean high-temperature glazes throughout history.[248] The silica-alumina-calcia mixture is also used industrially today for the manufacture of certain types of glass-fibre because of its useful viscosity.[249]

Eutectic Mixtures

All these effects are the result of the physical phenomenon of *eutectic mixtures*, that is the particularly low-melting blends that occur when two or more materials are mixed together. The process involved is shown in Figure 19, where the average melting-points of silica and sodium oxide are represented by the dotted line, but the heavier line shows the real and observed melting-points of the soda-silica mixtures.

[245] Kingery (1986), p. 162.
[246] Pierce & Watts (1952), pp. 220–2.
[247] Tauber & Watts (1952), p. 458.
[248] Wood (1994), pp. 52–3.
[249] Anon. (1988b), p. 50.

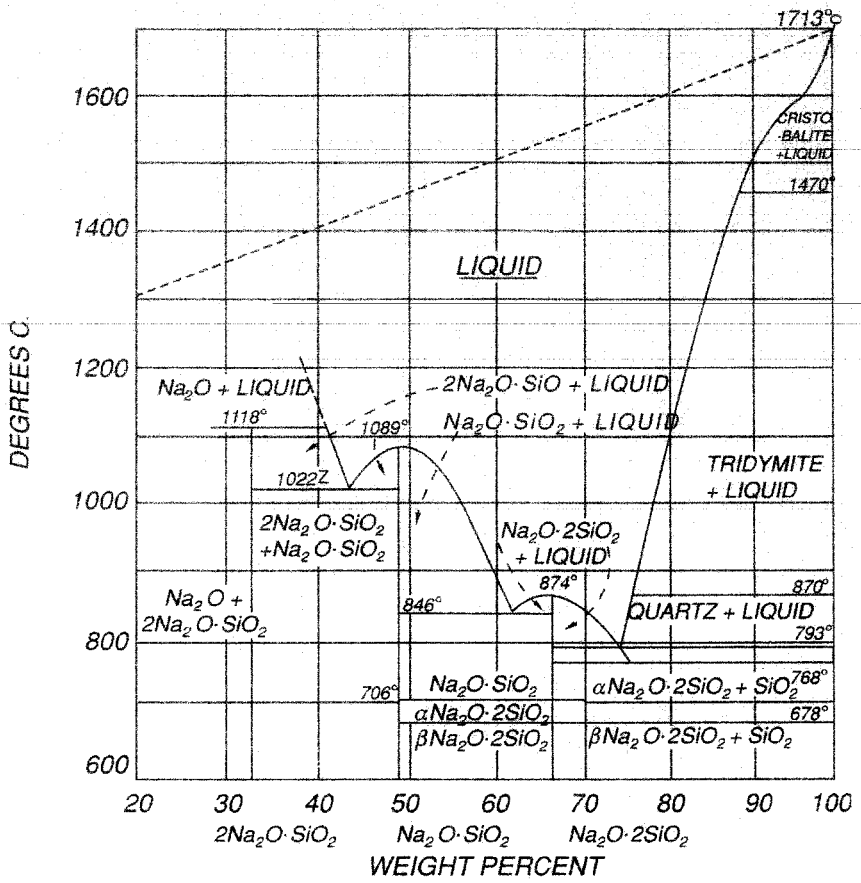


Fig. 19 Eutectic mixture in the SiO_2–Na_2O–CaO system

Figure 19 shows that quite small additions of sodium oxide cause a precipitate fall in silica's melting-point, and that the melting-points of these mixtures occur well below the 'predicted' line that connects and averages the melting-points of the two materials. While some blends between materials show only one eutectic mixture it is not uncommon for a series of eutectic mixtures to occur, as is seen in the Na_2O–SiO_2 system, with its three 'lows' on the 'liquidus' line:[250]

[250] Kracek *et al.* (1929), p. 1892; Levin *et al.* (1956), p. 39, fig. 19.

THE SILICA-SODIUM OXIDE SYSTEM

The silica-sodium oxide system is important in ceramic history because it became the basis of the world's first glazes, of which early examples have been found in Mesopotamia and dated to the -6^{th} to -5^{th} millennium.[251] These silica-soda glazes were used on artificial stone-based bodies, rather than on clays, and they pre-date the first production of glass (which also began in Mesopotamia) by some 2,500 years.

Typical bodies for these ur-glazes were worked talc ($Mg_3Si_4O_{10}(OH)_2$), which was then fired to mature the glaze and to create the stronger material, enstatite ($MgSiO_3$).[252] Quartz pebbles were also fired and glazed in a similar manner. The sources of fluxes for these early glazes appear to have been soluble alkalis from the ashes of saline-desert plants, as these are particularly rich in sodium oxide.[253] Almost from the start, copper oxide was used to colour the glazes turquoise-blue or turquoise-green, probably to evoke the character of real turquoise and malachite.

Not long after the glazing of natural stone was discovered the idea arose to pulverise the rocks, and then to mould the powders to give a greater range of forms and scale. This use of rock dust also allowed soluble fluxes to be added to the dampened bodies during manufacture. The fluxes could then migrate to the objects' surfaces as they dried, to give crystalline layers of alkaline salts. During firing, the crystallised salts attacked the body-materials, dissolving silica from them to create true glazes on their surfaces. These 'sacrificial' soda-rich glazes tended also to be coloured by copper compounds, in this case usually added to the body-materials before moulding.

Crushed quartz or silica sand came to be preferred for these rock-dust bodies, perhaps because the material gave bluer glazes when coloured with copper compounds than talc.[254] Another strategy, developed very early in the history of glazed faience, involved surrounding the objects to be glazed in a bed of quartz, alkali, lime, charcoal and some copper compound, and then firing the whole mass to earthenware temperatures.[255] During firing the surfaces of the objects became thinly glazed, and the 'glazing mixture' shrank away from the glazed artefacts. Reaction of the alkaline fluxes with the siliceous material beneath tended to continue until an alkaline oxide-silica equilibrium had been reached, and this often represented one of the higher-silica eutectic mixtures in the sodium-oxide/silica system. This was a fortunate effect as glasses richer in soda and lower in silica (that is towards the left of Fig. 19) may still be soluble after firing.

[251] Moorey (1999), pp. 168–9. This page citation refers to the latest reprinted edition of *Ancient Mesopotamian Materials and Industries* (see Bibliography C).

[252] Tite & Bimson (1989), pp. 88–100; Bouquillon *et al.* (1995), pp. 527–38; Tite *et al.* (1998), p. 112.

[253] Tite *et al.* (1998), p. 112, write: 'The principal source of alkali up to about 7^{th} or 6^{th} centuries BC was a soda-rich ash produced by burning plants that grew in saline (desert) environments.'

[254] Tite & Bimson (1989), p. 88.

[255] *Ibid.*, pp. 93–4. Tite and Bimson describe a modern mixture, obtained by Oliver Watson from Qom in Iran: 'This mixture which consisted of plant ash, hydrated lime, powdered quartz, copper oxide and charcoal was used either as received or after the addition of one part by weight of malachite to two parts by weight of the Qom mixture.' *Ibid.*, p. 94.

With increasing skill the scale of faience objects grew from the small and simply moulded to the truly colossal. The latter style of object is represented by a famous turquoise-glazed faience *uas* staff in the Victoria & Albert Museum (accession no. 437–1895). This stands more than two metres tall, is some 35 centimetres in diameter and dates to the mid –2nd millennium, about the time that glazes were first made in China.

Thousands of large faience tiles were also made to line rooms in Egyptian pyramids, while new faience colours – red, yellow, green, blue and white – were developed. Further complex techniques of painting and inlay were devised, and were often applied to faience vessels.[256]

Two important principles are evident in this ancient glazed-stone technology that can also be applied to glaze construction in general. The first is that a pure flux alone may be used to make a glaze, as it will attack the ceramic material beneath at the height of the firing, and then combine with the silica (and often the alumina) in the object's surface to make a true glaze. The second is that glazes often represent near-eutectic mixtures: through equilibrium being achieved during firing; through the attack of pure fluxes or a flux-rich mixture on the ceramic body; or even through the deliberate application of a true eutectic mixture to the object being glazed.

Glazes based on eutectic mixtures were (and still are) valuable not only for the ease with which they melt, but also for their good performance over a wider range of kiln temperatures than non-eutectic glazes.[257] A further advantage of 'eutectic glazes' is that they are more economical to fire as they melt at temperatures lower than other mixtures using the same materials. Their visual characters too are often superior to more random mixtures, probably because their constituents are so thoroughly integrated. Analysis shows that many historical glazes world-wide were based on eutectic mixtures, and these must have been identified, and then adopted, through centuries of empirical testing.

FROM GLAZE TO GLASS

The use of soda-rich 'sacrificial' glazes on materials such as quartz pebbles, carnelian, feldspar, talc and 'faience' (a synthetic quartz-rich body) spread from Mesopotamia to Egypt, and saw thousands of years of use in West Asia and as far east as Pakistani Balochistan, particularly in its turquoise form coloured by C^{2+} ions.[258] What is odd about this simple sodium-silicate technology is that it was not adapted for the glazing of ordinary clays for many thousands of years, during which time its use was restricted to non-clay siliceous materials or mixtures.[259] What seems to have been necessary before ordinary clays could at last be glazed successfully was the creation of the world's first successful *glass* technology. The key to this important

[256] Nicholson (1993), pp. 32–3; Tite *et al.* (1998), pp. 111–20.
[257] Watts (1955), pp. 343–52.
[258] Vandiver *et al.* (1992), pp. 519–25; Bouquillon *et al.* (1995), pp. 527–38.
[259] Spencer & Schofield (1997), p. 104.



Fig. 20 Full view of turquoise-glazed faience *uas* or sceptre depicting Horus, Egyptian, 18th dynasty, *c.* −1,570 to *c.* −1,342

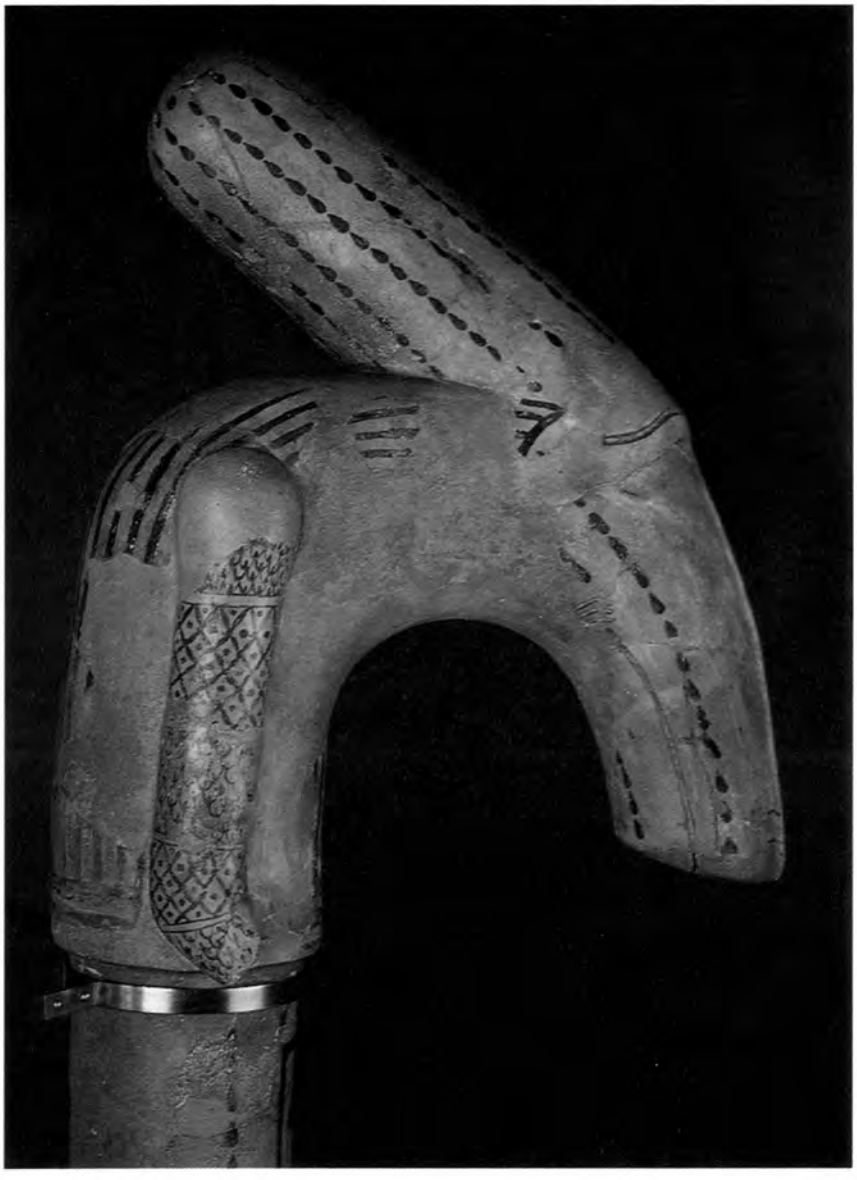


Fig. 21 View of head of turquoise-glazed faience *uas* or sceptre depicting Horus, Egyptian, 18th dynasty, *c.* −1,570 to *c.* −1,342

Table 3 *Eutectic mixture in the SiO_2–Na_2O–CaO system compared with Babylonian glasses and glazes, and ancient Egyptian and modern glasses*

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	BaO	B_2O_3	Total
Ternary eutectic m.p. 725°C[a]	73.1			5.0			21.9			100
Babylonian glass −15th to −14th centuries	63.9	0.7	0.2	5.9	6.3	4.5	18.3			99.8
Babylonian glaze *c.* −580	64.7	1.0	1.0	5.9	4.6	4.6	18.2			100
Egyptian glass *c.* −1550 to −1163[b]	66.5	0.6	0.4	5.9	5.1	2.5	19.1			100.1
Modern container glass[c]	72.3	1.0	0.0	8.4	1.95	1.05	15.15	0.25	1.25	101.35

[a] Levin *et al.* (1956), p. 39, fig. 19.
[b] Research Laboratory for Archaeology and the History of Art, Oxford (Unpublished).
[c] Anon. (1988), p. 35 (average of a range of modern container glasses).

advance lay in the more systematic use of another oxide – calcium oxide – in the soda-silica mixtures in order to create the exceptionally stable material known as soda-lime glass. This essential calcia was often present in ash or as shell in the sands used for glass-making, but the consistent levels of calcium oxide found in ancient glasses suggests that some degree of conscious control was practised to optimise these percentages.[260] Once this oxide-balance had been achieved, soda-lime glasses of very high technical quality could be made. Furthermore, this material was also suitable for the glazing of clays. In fact so successful was the early Near Eastern soda-lime glass composition that it is still the basis for ordinary container and window glass world-wide. The usefulness and stability of this composition may, once again, have owed something to its near-eutectic basis (Table 3).

The soda, potassia and magnesia contents of the Babylonian glasses and glazes may derive from alkali-rich evaporites, or they may come from alkali-rich plant ashes. In fact this is one of the thornier problems of early glass technology, and a good deal has been written on the question.[261]

[260] Henderson (2000), p. 28.

[261] See Henderson (1985), pp. 272–6, and Henderson (2000), pp. 48–51, for a review of the 'ash vs. evaporite' problem. Also Shortland & Tite (2000), pp. 141–51. In 2000 Henderson summarised the current view of the situation regarding ancient glass thus: 'There appears to be at least two separable glass technologies identifiable: the first consists of low magnesia soda-lime glass (LMG) which contains less than 1% magnesia and correspondingly low potassium oxide levels at below 1.5%. It is likely that for these a mineral such as natron was used for the alkali. The glasses of this type are Mesopotamian and Minoan, as well as cobalt-blue glasses from Egypt . . . The balance of the Egyptian glasses are of the second compositional type, high-magnesia soda lime glass.' Henderson (2000), pp. 58–9.

THE USE OF CALCIA AS A STABILISER

The world's first soda-lime glass artefacts have been found in Mesopotamia at sites such as Nuzi in Iraq,[262] and this new technology soon spread to Egypt. The ceramic aspect of this story, the first use of soda-lime glazes on common surface clays to create true earthenware glazes, seems also to have happened in Mesopotamia, *c.* –1,500, some 3,000 years after the first sodium-silicate glazes were used on non-clay siliceous bodies.[263] As with Near Eastern stonepaste wares (see pp. 735–8), the most popular colours used with these new soda-lime glazes were turquoise-blues and turquoise-greens from dissolved cupric oxide (*c.* 2–4% CuO). Such colours have always had a strong appeal in West Asia, initially for their turquoise and malachite associations, but also for their capacity to evoke the colour and character of deep clear water. The soda-lime basis for these glazes (which tended to mature between about 1,000° and 1,100°C) spread later throughout the Islamic world. There they survive into modern times, still often coloured turquoise-blue and turquoise-green from dissolved copper (II) ions.

EARLY CHINESE GLAZES

While perhaps not immediately and obviously relevant to early Chinese glazes, the above notes on early West Asian glass and glaze technology are included here for three reasons. The first is to sketch in the fundamentals of glass and glaze technology through an examination of their first manifestations in ceramic history. The second is to emphasise the importance of eutectic mixtures in any consideration of historical glaze development. And the third is to indicate the nature and level of glass and glaze technology that operated in the world at the time that the first glazes were made in China, in the mid –2nd millennium. A full discussion of China's substantial and distinctive contributions to ceramic glaze technology appears in Part 5 of this volume.

SUMMARY OF PART I: 'SETTING THE SCENE'

Joseph Needham warned about analysis of social context and the 'difficult questions of status', but was constrained to include a section elucidating the status of engineers and inventors in the book devoted to mechanical engineering.[264] In a similar vein, the views of ceramics held by consumers, patrons and cultural commentators in early China have been outlined. Interest in this topic was not concerned with the monetary value of pottery (which would in many cases be difficult to determine) but rather in its importance in relation to other materials, its purpose in indicating the rank or wealth of owners and its value (or otherwise) in ceremonial operations.[265]

[262] Vandiver (1982), pp. 73–92.
[263] Moorey (1999), pp. 159–60.
[264] Needham & Wang (1965), pp. 21–42.
[265] Research prepared for this section was included in Kerr (1997).

The status of potters themselves was touched on, and on the official departments controlling their work.

Secondly, textual evidence concerning pottery and porcelain manufacture in the post-Han period was considered. The body of Chinese material is patchy in its coverage of the subject, tending to concentrate on certain famous kilns. Not surprisingly, extant texts are available in greater numbers, and are more detailed in scope, for the later dynasties of Ming and Chhing. By the end of the Ming period the first European-language enquiries into porcelain manufacture were appearing, a trickle of information that has swelled to a +20th- and +21st-century flood of information on all aspects of ceramics.

Thirdly, the chief subject of this volume was introduced, namely the technology of Chinese ceramics. Preliminary remarks on raw materials, the nature and formation of clays, forming and firing, and the development of glasses and glazes, formed the basis of a discussion that will be elaborated in Parts 2–6 of the book. The range of ceramic output in China, from the Neolithic to the present day, was formidable. But, despite this enormous variety of production, there did exist a unifying principle that drew myriad objects together. The principle was that wares from the same areas of China used essentially the same range of raw materials, often for many thousands of years, but often too for distinctly different purposes. Chinese ceramics can therefore be approached usefully from the standpoint of its raw materials and their origins. The fact that wares of such technical and aesthetic merit could have been made in such direct ways from local resources reflected not only of the unusual wealth of ceramic raw materials that exist in China, but also the exceptional insight, subtlety and imagination exercised by Chinese potters.

PART 2: CLAYS

EARTHENWARES AND STONEWARES TO THE HAN DYNASTY

As discussed in Part 1 of this book, despite the size of China and the antiquity and continuity of its ceramic history, some major principles can be identified that govern the nature of its clay resources. Chief amongst these is the difference between clay-rich northern wares and quartz-rich southern materials. This is itself a reflection of the separate geological histories of the North and South China blocks, before their collision and attachment along the Nan-shan Chhin-ling divide.

THE NORTH–SOUTH DIVIDE AND ITS INFLUENCE ON CHINESE CERAMICS

As mentioned and discussed in greater detail in Part 1, large-scale tectonic events during the Triassic period (247–209 million years ago) fused the Chinese mainland together from a number of quite separate landmasses, the most significant of which were the large North and South China Blocks. These drifting mini-continents had followed independent geological careers before they collided to make China's present-day landmass, and the regional variations that are so evident in the compositions of Chinese ceramics seem to match their ancient outlines. The main line of fusion between these ancient blocks also provides the roughly equal division between the north and the south of China, as understood by the Chinese people. Ceramics, with their close association with regional geology and topography, are a particularly rich expression of this great north–south difference in China. As various sections of this book will demonstrate, north–south effects operate in clay-bodies, kilns, fuels, workshop designs and glazes, and in the general chronology that lies behind the appearance of such major Chinese wares as glazed stoneware and porcelain.

THE NORTH–SOUTH DIVIDE IN CHINESE CERAMICS

The Chhin-ling mountain range acted as a physical barrier to the southwards spread of loess. Reworked alluvial loess spills over the north–south divide towards the East China Sea, but the great loess-based ceramic industries of north China operated largely in Kansu, Shansi, Shensi, Honan and Hopei provinces. No earthenware material of equivalent versatility occurs in south China. It is in high-temperature clay bodies, however, that the north–south distinction operates most strongly. The raw materials used for stoneware and porcelain show the most faithful 'shadowing' of the ancient tectonic domains, with most of these clays showing more

than 25% aluminium oxide by fired weight in the north and less than 23% Al_2O_3 in the south, with associated lower and higher silica percentages in the north and south respectively. Southern stoneware clays and rocks also tend to be richer in alkaline fluxes, particularly potassium oxide from their high contents of secondary hydro-micas. The same clay-rich (north) and quartz-rich (south) principle carries through to east-central China where a north-eastwards deformation of the South China block was caused by the Than-chheng – Lu-chiang Wrench Fault System 郯城 – 廬江扭捩斷層系統, a geological feature that will be discussed in more detail in Part 7 of this volume.

North Chinese ceramic materials respond well to slow firing, such as by coal in *man-thou* kilns 饅頭窯, while southern materials are better fired fairly rapidly, for example by wood or scrub in dragon kilns 龍窯. These kilns are described in detail in section 3 of the book, and we shall see that although a number of *man-thou* kilns appear in south China, particularly for firing bricks in reducing atmospheres, the classic dragon kiln seems virtually unknown in the north. Fuels provide a further north–south distinction, for whereas kilns in both north and south China used wood until the later +10th century, after that time coal gradually became the preferred northern fuel. The switch to coal firing in north China does not seem to have involved any major relocations of north China's ceramics industries, as the geologies that provided accessible stoneware and porcelain clays seem also to have been associated with north China's vast coal fields, among the more extensive in the world.[1] By contrast, firing with wood, scrub and reeds continued for high-temperature wares in south China until relatively recent times.

North–south differences in Chinese vernacular architecture seem also to apply to Chinese ceramic workshops, part of the tradition of 'Manufacturing Methods and Sequences' elaborated in Part 4 of this volume. There is a long tradition in north China for subterranean and semi-subterranean house construction, particularly in the loess lands. Both excavation and modern fieldwork show extensive use of these principles in ceramics kilns and workshops in north China.

One of the challenges to potters working in the north lies in coping with extreme winters, and the traditional heated, raised platform called *khang* 炕 was vital to this end, for it prevented wares from freezing. In south China the climate is kinder, and there the authors have observed traditional ceramics workshops and kilns made from tied beams, with rice-straw thatching reaching practically to the ground.

The layouts of traditional Ching-te-chen 景德鎮 workshops were also classically southern and owed much to the southern courtyard system of building, with many operations taking place outdoors, or on staging beneath deep verandas.[2]

[1] China's coal reserves have been estimated as about 1–1.5 trillion metric tonnes, third in the world after the United States and the former Soviet Union. Whitaker & Shinn (1972), p. 450. For a detailed account of the historical use of coal in China, see Golas (1999), pp. 186–202.

[2] Xiong Liqing & Lu Ruiqing (1985), p. 68, and unpublished poster-paper at the conference. See also map of the imperial factory at Ching-te-chen on p. 187.



Fig. 22 *Man-thou* kiln making blackware and dug into the earth, at Shen-hou 神堠 in Honan province, +1985



Fig. 23 Thatched kiln at Ching-te-chen, +1982

GLAZES

The most characteristic difference between northern and southern Chinese high-temperature glazes lies in the use (or non-use) of body-materials in the glaze recipes, a topic investigated in Part 5. From at least the early +7th century in north China, porcelain potters abandoned the traditional southern practice of basing their glazes on the same material as was used to make the wares, perhaps because the aluminous northern bodies proved unsuitable as major glaze materials. The practice spread from northern porcelain kilns to stoneware manufacture.

NORTH CHINA AND LOESS

Returning to the earliest and longest-lasting ceramic tradition of north China, we note that it was based on loess. This is not surprising, for the loess deposits that blanket the original landscape of north China are the deepest and most extensive in the world. A region of some one million square kilometres is covered by vast deposits of loess in both its wind-blown and water-deposited forms. In its aeolian beds (north-western China) the material occupies nearly 400,000 square kilometres, while at Lan-chou 蘭州 (in the far north-west, and near to its desert source) the loess may be up to 300 metres deep. Further from its origins the average depth of aeolian

Chinese loess is about 40–80 metres.[3] The reworked and water-borne loessic silts of north-eastern China cover some 600,000 square kilometres and may be 800 metres or more in depth, where their accumulation has been assisted by the constant flooding of silt-laden rivers and some sinking of the underlying bedrock.[4]

The word loess derives from the German *löss* (loose). True loess is a wind-borne dust, derived mainly from the mechanical weathering of igneous rocks, in the case of China from the Inner Mongolian deserts. Loess tends to accumulate in uncompacted beds that differ from the dense and heavy strata typical of water-transported sedimentary clays. Even when aeolian loess is reworked and redeposited by water, it is still less dense than true clay as its low content of fine platy minerals gives less compacted sediments.

China's loess derives from the freezing and thawing of igneous rocks in the arid Tenger and Ordos deserts of Inner Mongolia, along the southern margins of the Greater Gobi desert. For the last 2.4 million years the material has been blown south-east by prevailing winds over the ancient limestone, clay and sandstone landscapes of northern China.[5] Loess deposits show increasing fineness the further they have been blown. Materials closest to the desert sources are called sandy loess, further away silty loess, and further still clay loess.[6] However, these terms refer more to the particle sizes of the materials concerned (typically 10–50 μm) than to their essential mineralogies, which remain fairly constant across the area. Chinese loess consists mainly of minute grains of quartz, feldspar and mica, with small amounts of kaolinite, illite (a hydro-micaceous clay) and calcium carbonate. The iron oxide content tends to be about 6%, mainly in the form of yellowish limonite-type minerals such as geothite. It is these iron minerals that give the characteristic pale ochre-brown colour to the *huang-thu* 黃土 ('yellow earth') of northern China.[7]

Despite its relatively loose compaction, loess is capable of standing in tall cliffs with near-vertical faces, a very different behaviour from ordinary clay, which tends to weather into shallow slopes. Theories on this capacity for huge accumulated deposits of loess to hold their forms (unless eroded by fast-running water) include: electro-static attraction between superfine particles and the presence of 'clay bridges'; tensile water-films between the larger particles; and cementation of its mineral-grains by secondary calcite.[8] The unusual stability of loess deposits has been exploited for thousands of years in north China, where loess cliffs, banks and plains have been excavated and tunnelled to make houses, workshops and barns.

[3] Pye (1987), p. 200.
[4] Tregear (1980), p. 216. Tregear writes: 'The mind boggles at the amount of material that has been deposited, for this trough, a geosyncline, into whose maw seemingly endless food can be poured, since the rate of sinking maintains an equilibrium with the rate of deposition . . . The Hwang-ho's [Yellow river] silts and sands are at least 2,800 feet thick.'
[5] Ding Zhongli & Liu Dongsheng (1992), pp. 390–406.
[6] Burbank & Li Jijun (1985), p. 430, fig. 2.
[7] Liu Tung Sheng (1988), p. 88.
[8] Pye (1987), p. 220.

The usual practice with these man-made caves has been to build a brick front wall, often with an elaborate doorway, against a loess cliff, and then to excavate into the hillside through the doorway opening. A typical loess cave (six metres deep, three metres wide and three metres high) may take 40 days to excavate and three months or more to dry out.[9] When complete, the cave would be lined with a lime-loess plaster mix, and fitted with a *khang*.[10] As Gideon Golany notes, such cave-houses are:[11]

> remarkably warm in winter and cool in summer, an important factor in a region with a stressful continental climate of very cold winters and hot summers.

Large pottery workshops, made in this way, still operate in Shensi and Honan provinces (see Fig. 22), and essentially similar workshops have been excavated at Huang-pao 黃堡, near Sian, where they were used for making lead-glazed wares in the Thang dynasty.[12] The Huang-pao excavations show evidence of having been flooded and abandoned in haste, and indicate that some northern potters lived and worked within the same excavated spaces.

Troglodític villages dug into loess cliffs or flat loessic plains are also a common sight in north China, with the scale of the excavations depending to some degree on the mineralogy of the local loess, with higher calcia contents permitting shallow unsupported vaulted roofs up to five metres across. To some extent too, the cross-sections adopted for these caves reflect differences in local geology, with parabolic or 'gothic' cave-sections appearing where the loess is less cohesive.[13]

As described elsewhere in these volumes, the compaction of loess between temporary wooden shuttering, by stamping the material with thick wooden posts, to built-up solid layers a few centimetres at a time, has been a key building process in China since the late Neolithic.[14] Huge city walls were built in this manner in north China's Bronze Age that involved thousands of workers and

[9] Golany (1992a), pp. 32–3.

[10] Myrdal (1951), p. 13, records an account by cave builder Mao 毛 living in Shensi province: 'You don't need so many people to build an earthen cave. An ordinary cave of normal size, 18–19 chi [chhih 尺] long, 9–10 chi high and 8–9 chi wide, including making the kang [khang] and cooking stove and chimney, takes about forty work-days . . . At first, caves are slightly damp, but they dry out after three or five months. If the soil is of good quality and hard and firm, you can then build additional caves and store rooms leading off from the first cave. But if you do that, you make the passages between them rather narrow, roughly two by seven chi.' (1 chi [chhih] is about 33.5 cm). Ronald Knapp (2000), p. 98, notes that cave excavation was deliberately measured: 'not only because the farmers do the work themselves but also . . . for the soil to dry out slowly, a condition necessary to maintain its stability.'

[11] Golany (1992b), p. 152. Golany gives temperatures of approximately 10°C in winter and 25° in summer as being typical of loess-cave-houses (*ibid.*, p. 153).

[12] Tu Pao-Jen & Cho Chen-Hsi (1987), pp. 16–18.

[13] Golany (1992b), p. 151, notes: 'Even today some thirty to forty million people, about 20% of the population of the five provinces [i.e. Shansi, Honan, Shensi, Kansu and the Ninghsia Hui Autonomous Region 寧夏回族自治區] live in underground villages that vary in population from a few hundred to a few thousand.'

[14] Needham *et al.* (1971), p. 39.



Fig. 24 Cave-houses dug into loess cliffs near Sian, +1976

many years in their construction. At the mid Shang dynasty city at Cheng-chou in Honan province the original Bronze Age rampart still survives as a short section.[15]

[15] An Chin-Huai (1961), p. 77, calculates that the Shang dynasty walls at Cheng-chou, Honan province, could have taken nearly three million cubic metres of loess to build, and needed the labour-equivalent of 10,000 workers toiling for eighteen years. A further account of the construction of the Cheng-chou walls is given in An Chin-Huai (1986), pp. 22–8. An notes from pottery incorporated in the walls, and from other evidence, that the 'walled enclosure of the Cheng-chou Shang dynasty city cannot have been constructed at any time later than the Lower Erh-li-kang period'. *Ibid.*, p. 27.



Fig. 25 Shang dynasty city walls at Cheng-chou, +2001

PALAEOSOLS

Production of China's loess may have had some connection with tectonic events in the area, as well as with general global cooling. When the Indian subcontinent collided with Asia, the raising of the Tibetan plateau eventually interrupted monsoonal circulation, causing the climate of north China to become colder and dryer, and its vegetation sparser. This change occurred between the Late Pliocene and the early Pleistocene, making the accumulation of Chinese loess, geologically speaking, a relatively recent event.[16]

The building of the loess in north China seems to have been continuous for some 2.4 million years; indeed the process is still occurring.[17] For example, at Sian, the natural dust-fall accumulates at an average rate of 26 tonnes per square kilometre, per month, where the material has to be swept regularly from the huge hangar-like

[16] Pye summarises: 'It is not yet entirely clear whether the initiation of loess formation in China around 2.4 million yr BP was due to the onset of northern hemisphere cooling or to regional climatic and morphological changes associated with the uplift of the Tibetan Plateau. Both probably played a part.' Pye (1987), p. 249.

[17] 'The . . . loess/Red Clay boundary of 2.4 m.y. marks the beginning of the loess-dust accumulation . . . this boundary can be considered as the start of the Quaternary period in northern China when the climate deteriorated drastically from warm-humid to dry-cold.' Liu Dongsheng (1988), p. 55. Ding Zhongli *et al.* (1998), pp. 135–43, suggest that particle-size natures of these Pliocene red clays, examined at points over a 400-kilometre distance are, like the overlying loess itself, typical of wind-blown deposits. However particle-orientations suggest that the red clays were transported by the westerlies, rather than by the winter monsoonal winds that seem to have distributed the ochre-coloured loess that formed later.

roof that protects the terra-cotta warriors, some 30 kilometres east of the city.[18] The climate in north China over this loess-building period has not been uniformly cold, however, as at various periods between the ice ages, warmer and wetter periods have intervened. One theory for these warmer intervals is that they coincide with the precession of the equinoxes in roughly 25,000-year cycles. That theory is supported by study of both terrestrial and marine loessic sediments in China and in the Yellow Sea.[19]

Evidence for these interglacial warmings may be seen in many loess cliffs as darker bands of deposited material. For example, in the 'Pao-chi section', about five kilometres north of the city of Pao-chi 寶雞 in Shensi province, 37 of these darker palaeosol bands may be counted.[20] These *palaeosols*, or ancient soils, are more clay-rich than the surrounding loess as the climates that existed when they were deposited allowed more chemical weathering to occur.[21] In the manufacture of ceramics in north China, both the regular loess and the more plastic palaeosol layers were exploited by the potters, who matched the various qualities of their raw materials to the plastic demands of their processes.[22]

Loess and Fertility

Because loess is essentially rock-flour, rather than clay, it is rich in trace elements that are vital for plant life. These tend to be removed by heavy chemical weathering, but survive in the lightly weathered loess. Such elements help account for the high fertility of loess, and for its popularity with farmers world-wide, where, in its primary aeolian state it covers some 5% of the Earth's land surface.[23] The loose structure of the material also makes it easy to cultivate, and plant roots penetrate deep into the silty soil. Loess also drains well, with water tending to accumulate at the horizon between the loess and the rock or clay beneath, where it may often be reached by wells. Loess is therefore an ideal material for agriculture, and the widespread stripping of field surfaces for brick-making (a common sight in north China) which, in most agricultural situations would be more than foolhardy, in China merely exposes fresh and fertile surfaces for cultivation.

As is well known, however, the treacherous climate of north China has often confounded this potential fertility, and the many long droughts of China's history have caused terrible famines. Often too, when the rains fall, they arrive as heavy cloudbursts or hailstorms that cause rivers to burst their banks, and crops to be flattened

[18] Cheng Derun & Si Ru (1989), p. 496.
[19] Burbank & Li Jijun (1985), pp. 430–1. Pye (1987), p. 249, notes this work, but adds that the authors: 'do not elaborate on a possible causal connection.'
[20] Rutter *et al.* (1991), pp. 1–22.
[21] Derbyshire *et al.* (1995), pp. 681–97.
[22] Wood *et al.* (1992), p. 137.
[23] Pye (1987), p. 200.

or washed away.[24] To some extent the massive deforestation that began in this area in the late Neolithic and early Bronze Age, and accelerated in the pre-industrial period, permanently destabilised the climate of north China.[25] Perhaps the most dramatic effect of the deforestation of the northern loess lands has been a fall in the water table of some 5–15 metres in most areas since early historical times.[26] Until the Western Han dynasty the region was rich in woodlands that included oak, bamboo and mulberry, and was also cultivated for rice. Lakes and springs were abundant, and some areas were marshland with thriving birdlife. Much of the region is now dusty and treeless, and deeply cut by gullies that further depress the water table and bear away loess. This nuclear region for China's great agricultural civilisation is now 'largely turned to barren land after long-term vegetation destruction induced mainly by human activities, and partly by climatic change'.[27] Erosion of the loess areas is now occurring at a rate some 39 times its level of deposition[28] but, because the loess lands are too valuable for large-scale reforestation, irrigation has to serve where local rainfall is erratic.

The Use of Loess in Chinese Ceramics: The Neolithic Period

Chemical and microstructural analyses of ceramics, from across north China, show that loess was often used for making pottery vessels, particularly in the Neolithic period. The best evidence for its use is seen in the unusually high levels of sodium oxide (typically 1.25–2.5% Na_2O) that occur in the body analyses of north Chinese Neolithic earthenwares and the fine, slightly silty textures of the ceramics concerned. Sodium oxide figures in this order are rare in ordinary sedimentary clays, which tend to have Na_2O levels below 1%. The main reason for this difference is that many true clay minerals derive from the chemical alteration of sodium feldspar, and the sodium ions that are liberated by the reaction tend to be borne away in rainwater, and eventually become separated from the newly deposited clays. In the loess material these high soda figures represent the presence of unaltered sodium feldspar crystals, still abundant in the fine wind-blown rock-flour.

The development of different phases of Neolithic culture in north China is very complex, and the picture is added to each year with fresh archaeological

[24] For the village of Ting-hsien 定縣 in Hopei province a record of calamities kept for the period +106 to +1926 included: Floods, 35; Droughts 28; Locusts 21; Hail 17; Earthquakes 14 and Epidemics 8. 'Good years' were recorded too, and these amount to 7. Gamble (1954), pp. 454–5.

[25] Yang Gen *et al.* (1985), p. 24. Knapp (2000), p. 193, also writes about loess plateau deforestation. See also Fang Jingqi & Xie Zhiren (1994), pp. 983–99.

[26] Fang Jingqi & Xie Zhiren (1994), p. 994.

[27] *Ibid.*, p. 983. The high fertility of loess remains, but in many cases the gully-eroded topology has made farming difficult.

[28] Liu Dongsheng (1988), p. 145, gives the possible depositional amount of loess that has accumulated since the Pleistocene as: '1.89–9.47 × 10^{15} tons in the loessial area of China and 1.19–8.30 × 10^{15} tons in the middle reaches of the Yellow River . . . we calculate the erosion rate to be 363.08 g/cm^2 × 10^3 yr corresponding to 39.04 times the average depositional rate (9.30 g/cm × 10^3 yr).'



Fig. 26 Distribution of major Neolithic cultures, *c.* –6,000 to –2,000

discoveries.[29] The multiplicity of sites belonging to different cultural groupings or 'cultures' is shown in the map in Figure 26.

Broadly speaking, from the early Neolithic (*c.* −6,000) the vast sweep of land covered by loess supported several successive and sometimes overlapping cultures. A central area (covering eastern Shensi, Honan, southern Shansi and southern Hopei provinces) first saw the production of relatively coarse, reddish or greyish-brown, sandy earthenware, fired in the temperature range 700–960°C.[30] These early types were followed by more sophisticated styles of pottery.

A series of sites dating to the middle Neolithic (*c.* −5,000 to −2,500) across northern and central China are grouped under the name Yang-shao culture (see also pp. 3–5). From *c.* −5,000 a core area comprising Shensi, Shansi, southern Hopei, western Honan, eastern Kansu and eastern Chhinghai provinces 青海省, saw the production of both fine and coarse ceramics. Pottery was handmade by coiling with some moulding, was subsequently strengthened using paddle and anvil beating, while a slow wheel was employed to finish fine ceramics. Fine ceremonial ware was burnished and painted. Coarse ware for everyday domestic use was also carefully designed, for water-containing vessels were purposefully thick-walled and tempered with sand or mica, while cooking vessels were also thick-walled and fired to earthenware temperatures sufficient to withstand subsequent heat. In contrast, storage vessels could be made either coarse or fine, depending on function. Clay was also used to fashion spindle whorls, knives, sling-balls and net-sinkers.[31] A well-known site from this phase is Pan-pho, which we have already considered in terms of the status of its pottery goods on pp. 4–5. In Honan province also, distinctive pottery was produced that was first red and later included grey and brown wares.[32] White slip was widely used, and towards the end of the phase ceramics were wheel-made. The eponymous site of Yang-shao-tshun 仰韶村 is located in this area.

It is generally accepted that Yang-shao culture spread north and westwards from the central area, to Kansu and Chhinghai provinces. In those regions, some of the most distinctive Yang-shao type wares were produced, in the context of what is now called the Ma-chia-yao culture 馬家窯文化 (*c.* -3,800 to -2,000). Typical were large burial urns with narrow necks and two lug handles on the side, made at such sites as Pan-shan 半山 (*c.* -2,600 to -2,300). Many Ma-chia-yao wares survive in Western

[29] The most comprehensive record in English of the broad picture, together with extensive information on individual sites, is provided by Chang Kwang-Chih (1963, 1986). Good illustrations of Neolithic wares, divided by geographical location, is included in Anon. (1993). Li He (1996), pp. 16–25, provides an overview.

[30] Chang Kwang-Chih (1963, 1986), p. 94. Although there is argument about how to classify the sites, many group them together under the name 'Pei-li-kang culture' 裴李崗文化.

[31] *Ibid.*, pp. 109–23.

[32] The chronology of this area runs from *c.* −6,000 to −5,000, with a gap and then a later phase from *c.* −4,000 to −3,000. *Ibid.*, pp. 123–32.

Table 4 *North Chinese Neolithic ceramics probably made from loess (Throughout this volume the '-.-' symbol is used to represent 'not reported', while '0.0' signifies 'sought but not found'.)*

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Ig. loss	Total
1.	67.1	16.6	0.9	6.2	2.0	2.3	2.8	1.3	0.04	-.-	1.9	101.1
2.	68.6	14.0	0.8	6.1	2.3	2.4	2.7	1.35	0.05	-.-	1.5	99.2
3.	66.2	15.5	0.8	5.8	1.85	3.4	3.2	2.45	0.08	-.-	1.1	100.4
4.	67.7	15.9	0.8	5.7	2.6	2.4	3.0	1.8	-.-	<0.3	-.-	99.9
5.	63.5	15.2	0.9	6.0	2.65	2.4	2.8	1.6	0.07	-.-	5.4	100.5

1. Grey wares from Yang-shao-tshun, Honan province
2. Black pottery from Hou-kang 侯岡, near An-yang, Honan province
3. Red pottery from Kho-sheng-chuang 客省莊, near Sian, Shensi province
4. Painted red pottery from Pan-pho, near Sian, Shensi province
5. Black 'eggshell-thin' pottery from Chheng-tzu-yai 城子崖, Shantung province

museums, for these were among the earliest sites excavated by Western archaeologists.[33]

A north-eastern region covering present-day south-eastern Inner Mongolia, Heilungchiang 黑龍江, Kirin 吉林 and Liaoning provinces saw its own early developments in pottery-making.[34] By the -3^{rd} millennium, affinities in the repertoire of pottery forms and painted decoration indicated contact with central plains' Yang-shao cultures. Meanwhile, dramatically different developments were taking place further south. Potters of the Ta-wen-khou culture 大汶口文化 in Shantung province manufactured small numbers of fine white, grey and black wares as early as the beginning of the -4^{th} millennium. During the -3^{rd} millennium, craftsmen belonging to what is now termed the Lung-shan culture 龍山文化 perfected those traditions. A variety of thin-walled blackwares, and a smaller number of fine whitewares of startling sophistication, owed their carinated forms and surface polish to mastery of the fast wheel. Lung-shan culture diffused westwards from Shantung, and gained dominance over Yang-shao culture in Honan, Shansi and Shensi provinces.[35] Characteristic painted pottery was overlaid by grey and black wares of varying degrees of distinction.

[33] Important among them was the Swedish archaeologist and sinologist J. G. Andersson (+1874–1960), who dug at Yang-shao-tshun in 1920–1, in Liaoning in 1922, and in 1921–3 in eastern Kansu; see Chang Kwang-Chih (1963, 1986), pp. 138–9. Many of his splendid ceramics from Kansu province are preserved in the Museum of Far Eastern Antiquities in Stockholm, and his research recorded in issues of the *Bulletin of the Museum of Far Eastern Antiquities* (*BMFEA*), between +1929 and +1947. His obituary by fellow sinologist Bernhard Karlgren is in *BMFEA* 33 (1961), pp. v–viii, pls. 1–8.

[34] For further discussion of Neolithic pottery development in north-east China see Chang Kwang-Chih (1963, 1986), pp. 169–91; Barnes (1993), pp. 108–18; Nelson (1995).

[35] For discussion of Ta-wen-khou and Lung-shan, see Chang Kwang-Chih (1963, 1986), pp. 156–69, 242–80. Underhill (2002) has as her main theme the development of complex societies in the late Neolithic, in the Yellow river valley.

Table 5 *Effects of kiln atmospheres on the fired colours of loessic ceramics*

Red	Oxidised
Yellowish buff	Reduction-fired then oxidised
Grey	Fired and cooled in reduction
Black	Fired with an excess of black smoke which impregnates the body with particulate carbon

Some compositions for north Chinese Neolithic wares that show features described above, and which were probably made from loess, include those in Table 4.[36]

In the first four examples the material would have been wind-borne, but in the Shantung pottery reworked alluvial loess was probably used to make the vessels.

Although loess was important for these wares, it was not the only clay that was exploited by Neolithic northern potters. More ancient red clays, dating from Upper Cretaceous times, and found beneath the loess, were also popular, and the rather pale-firing calcareous clays used for Yang-shao culture wares in Kansu province may well have been made from this material.[37] Ceramics collections in Chinese museums also contain a few rare examples of northern Neolithic ceramics that are white or pale cream in their fabrics, and these more refractory clays are described in greater detail on pp. 120–3.[38]

Character of Loessic Neolithic Wares

Loess-based Neolithic ceramics are fine in texture, and may be red, yellowish-buff, grey or black. These various colours result from firing loess under different kiln-conditions, but they are not necessarily an indication that loess has been used to make the wares, as other iron-bearing clays can be fired to give similar results. The best visual indication for the use of loess, in the absence of chemical analysis, is its fine, uniform, smooth, but slightly silty texture, and the presence of occasional small holes in the surface where organic materials have burned away. The various fired colours, seen in these north Chinese loessic ceramics, were achieved in the ways listed in Table 5.

A few north Chinese Neolithic wares that are made from loess are rather pale, which can be a sign of above-average levels of calcium oxide in the raw materials, often combined with some reduction in the kiln. During firing

[36] Assessed from the close compositional similarities between these ceramics and the compositions of typical Chinese loess, together with the textures of the vessels concerned. The sources used are Yang Gen *et al.* (1985), p. 25 (1, 2, 3 and 5), and Freestone *et al.* (1989), p. 261 table 1 (4).

[37] Sundius (1959), p. 108. See also Freestone *et al.* (1989), p. 261, table 1, for typical compositions of Kansu Neolithic wares.

[38] For one example, see Anon. (1992), Department of Archaeology at Peking University, pp. 80–1, fig. 27.

calcium oxide combines with the iron oxides in the clays to produce yellow calcium silicates.[39]

Grey- and black-firing ceramics are typical of the later Neolithic periods in north China, and this fashion for producing grey ceramics survived in pottery vessels until very late in the Bronze Age (Eastern Han). In the form of greyish bricks and tiles, reduction-fired loessic clays are still widely manufactured in north China. The principle of reduction-firing iron-rich clays is also practised in the south, though with entirely different raw materials.

From Oxidation to Reduction in Neolithic Ceramics

The important changes that occurred in north China, from oxidised to reduced Neolithic wares (typically from the Yang-shao culture to the Lung-shan culture), may owe something to the greater fired strengths that can be achieved with reduction-fired ceramics. In these materials the iron oxide is in its iron (II), Fe^{2+}, rather than its iron (III), Fe^{3+}, state. Iron (II) oxide (FeO) acts as a body-flux above 900°C, when it reacts with fine silica in the clay material to create some iron-silicate glass. The small amounts of glass that develop between the mineral-grains in the body-structures of reduction-fired ceramics help bond the materials more effectively, and thereby improve their fired-strengths. Refiring tests with Neolithic ceramics from north China show no marked changes until 1,050°C is reached, but at 1,100°C most samples begin to melt. From these experiments it is believed that most northern Chinese Neolithic pottery was fired to temperatures between 950° and 1,050°C.[40]

Properties of Loess in Neolithic Wares

The sorting-by-particle-size that has occurred as the loess has been blown south-east from the Gobi desert, has created a fine and consistent material that can often be used as dug, without further processing. The unusually low true-clay contents, typical of loess, mean that its shrinkage in drying can be minimal. Only a couple of per cent linear has been measured in some samples tested, compared with up to 10% with more plastic clays.[41] Loess may also be dried and fired faster than most earthenware clays, again due to its unusually low levels of true-clay minerals and to its relatively open structure. Loess is therefore a very well-behaved ceramic material, with little tendency to form drying cracks, or to show distortions of the forms in

[39] Simpson (1997b), p. 54, writing on Mesopotamian calcareous clays says: 'They are rich in calcium carbonate, $CaCO_3$, which loses carbon dioxide on firing to temperatures above about 750°C and reacts with the clays in the ceramic body to form a range of calcium silicate compounds . . . Pale pinks, yellows, greens and whites are typical of the pots fired from calcareous clays.'

[40] Yang Gen *et al.* (1985), p. 24.

[41] Author's (NW's) tests in +1992.

drying. Its main drawbacks are rather low refractoriness (that is a tendency to melt in the kiln) and a poor resistance to thermal shock in its fired state, due to its high quartz content; Neolithic ceramics intended as cooking wares tend to show coarser structures, probably from deliberate aplastic additions.

Loess was particularly useful for wares that were made by the coiling-beating-and-scraping process, as this technique works well with materials of lower plasticity than those used for throwing. Where loess was used for thrown wares, as it often was in the Han dynasties, more plastic varieties were preferred, probably taken from the more clay-rich palaeosol layers.[42] These wares show higher alumina and lower sodium oxide contents in the fired materials (indicating higher contents of true-clay minerals), and they are also richer in ultra-fine mineral-grains, when examined microscopically.[43]

The later Neolithic fashion for grey (reduction-fired) loess-based ceramics continued into the Shang dynasty, when besides vessels, potters also made water pipes from the same material.[44] They also pioneered the use of the loess for making the fired ceramic piece-moulds, used for casting bronze. This was one of the most important uses of loess in China's ceramic history.[45]

Loess in Shang Dynasty Ceramics and Bronze-Casting

Chinese bronzes show the most sophisticated use of ceramic piece-mould casting in any world tradition. The scale, precision, complexity and artistic quality of Shang dynasty bronzes achieved with this technique are all outstanding. A large element in the success of the process lay in the adoption by early bronze-founders of loess as the raw material for the production of ceramic piece-moulds, and these fired loess piece-moulds became the basis of Chinese bronze-casting in north China for nearly 2,000 years.

The sophisticated casting technology of Shang dynasty China seems to have had its origins in a simple way in the later Neolithic in Kansu province, when bronze knives were cast in open moulds in the period -2,700 to -2,000. Slightly later in that same area objects were also cast from stone moulds, the cast bronze reworked by hammering. By the Hsia dynasty axes, sickles, awls, chisels, spearheads and arrowheads were all made in Kansu province from bronze, with most examples cast and some cold-worked. By the early Shang dynasty hollow bronze vessels were being cast in fired-clay moulds, with some vessels appearing to be copies of beaten-metal forms.[46]

A natural material for making these early casting moulds would have been loess, already familiar as a mainstay of north Chinese ceramics production. Although

[42] Wood *et al.* (1992), p. 137.
[43] Zhang Zizheng *et al.* (1986), p. 111.
[44] *Ibid.*
[45] Gettens (1969), pp. 107–14; Freestone *et al.* (1989), pp. 270–1.
[46] Muhly (1986), p. 14.

loess begins to melt at about 1,100°C, much lower than the typical temperature of bronze in its liquid state (*c.* 1,150°C),[47] molten bronze chills as it hits the moulds and therefore has little time to melt the mould-material itself.

The particular virtues of fired loess as a bronze-casting mould-material are its fine particle-size range, combined with high porosity. The latter quality is due to the blocky nature of most of its constituent minerals, which however closely packed will tend to have spaces between the crystal grains (raw materials rich in platy clay minerals are much denser when fired). This open nature of low-fired loess is useful because it allows the gases contained in the molten bronze to escape into the porous mould, avoiding pores and flaws in the cast objects. Its friable nature also allows it to be knocked and scrubbed away easily from the finished bronze after casting. Low-temperature firing of the moulds (probably to below 800°C) also improved the resistance of the material to thermal shock in casting, as the heat-expansion was accommodated within the moulds' porous structure.

In the best Shang dynasty bronzes it is almost impossible to see where the joins between the separate mould sections occur and, on some examples, the carved details, reproduced by the loess moulds from the original models, may be as fine as a fingerprint. This combination of fine surface detail, with exceptional dimensional stability, is a most unusual virtue in a ceramic material. When these features are combined with a good high-fired porosity, they help to account for the outstanding technical qualities of northern Chinese bronzes.

Detailed analyses of Shang dynasty bronze moulds have shown typical loessic structures, with chemical compositions that suggest the use of the most lightly weathered (that is the lowest-clay) materials.[48] One feature so far studied by scanning electron microscopy is the lack of ultra-fine fractions in the fired mould-materials.[49] This may have been due to the mould-makers' choosing the least-weathered varieties of loess from the types available. But another explanation may be that the very finest fractions were deliberately washed away during the material's preparation (easily managed by stirring up the loess with an excess of water and pouring off the top layer that stayed in suspension). This lack of very fine particles made the shrinkage of the loess even lower than usual, and also made the material more porous when fired, because the interstices between the mineral crystals were not packed with still finer mineral-grains. However, the general fineness of the remaining loess was still entirely adequate for successful transfer of the model's detail.

Refractoriness

If there is one potential disadvantage to loess as a bronze-casting mould-medium it must be its tendency to melt, and there seems some evidence that Shang dynasty

[47] Chase (1983), p. 105.
[48] Freestone *et al.* (1989), p. 253.
[49] *Ibid.*, pp. 269–70.

bronze-casters avoided this hazard by a number of strategies. One approach was to place loess cores in thicker areas (such as handles) to limit the thickness of the bronze in these areas, so the metal cooled quickly. In other cases, notably the heavy legs on some tripod vessels, copper bars have been found that were placed in the moulds before the bronze was poured. These would have acted as effective 'heat-sinks' that chilled the molten bronze before it could melt the surrounding mould-material.[50]

To anyone familiar with the problems of precision-work with ceramics, Shang dynasty bronze-casting moulds appear today as disposable masterpieces of ceramic design and engineering. They were far more accomplished in their complexity, accuracy and dimensional stability than anything attempted in domestic or ritual ceramics. Their production would be a serious challenge for any modern mould-maker, but they were used routinely in China to cast ritual bronze vessels that varied in scale from a few centimetres in height to well over a metre, and in weight from a few grams to more than three-quarters of a tonne. The ornament on Shang dynasty bronzes can be so fine that it needs a hand-lens to resolve, or so broad that it may be seen from many metres away. The debris from used and discarded bronze-casting moulds in north China shows beyond doubt that loess was the main mould-material in China's Bronze Age, with a structure and physical behaviour that made it ideal for this purpose. Much of the success of bronze-casting in northern China must therefore have depended on the numerous subtle ways in which the essential nature of this material was exploited.

The Use of Loess in Building Materials in Early China

The technical qualities that made loess so valuable for bronze-casting moulds (low drying shrinkage, stability in low-temperature firing and capacity to take very fine detail) were also helpful in the making of high-quality architectural ceramics. Although rather less glamorous than the casting of bronze vessels, the 'heavy-clay goods' that built houses, protected bastions and provided clean water were of great importance to daily health and comfort. In ancient China, and continuing down to the present day, many of those products were made from ceramic. Recent archaeology has revealed the advanced technical and organisational skills needed to ensure large-scale production of architectural ceramics. Many items are also very beautiful, for they were formed and patterned with great care. Analytical studies on a range of architectural ceramics from north China, ranging in date from the Shang dynasty to Chhing dynasties, have shown a remarkable standardisation of raw materials and firing processes. It was only after the end of the Western Han dynasty

[50] Chase (1991), p. 32. Chase suggests that the copper cores discovered in the cylindrical legs of late Shang dynasty *ting* 鼎 vessels were designed to prevent excessive shrinkage of the bronze in cooling, and the consequent hot-tearing where thicker metal met the thinner metal of the same vessel. However, it is possible that the copper cores prevented both mould-melting and hot-tearing.

(–8) that some tiles began to be thrown on a wheel; prior to that time, all pipes, bricks and tiles were hand-constructed.[51]

The observant Sung Ying-Hsing 宋應星 summed up the importance of architectural ceramics in *Thien Kung Khai Wu* (The Exploitation of the Works of Nature, +1637):[52]

> People have such diverse needs for ceramics that even if 1,000 potters labour daily fashioning ceramics from water and clay and then firing the clay, they cannot satisfy the demands of a large country. Houses are built as shelter against wind and rain, so tiles are needed. Rulers have to build strategic defence works to protect the country, so city walls and ramparts are built of bricks and invaders are kept out.

PIPES AND WELLS

China has the longest, continuous production of ceramic building components in the world, from the Neolithic era down to the present day. Fired pottery seems first to have been used in the late Neolithic (*c.* –2,500 to –1,500) to make pipes,[53] and this was associated with the manufacture of ceramic sections to line wells. The Neolithic invention of drainage and water conduits was the most significant contribution made by ceramics to public hygiene until the manufacture of modern porcelain sanitary ware in the early +20th century.[54]

Originally, pipes and wells had been constructed from wood, which being highly perishable mostly does not survive. Occasionally, however, the right environmental conditions caused fragile materials to be preserved. An early Neolithic well in Chekiang province, belonging to what archaeologists have termed the Ho-mu-tu culture 河姆渡文化 and dating to *c.* 4,000 to –3,300, had its upper section reinforced with timbers. Interlocking lengths of wood lining all four sides of a well right down to the bottom were employed in a well in Honan dating to *c.* –2000.[55] In April +1982 archaeologists excavated a tubular wooden well at Chia-shan 嘉善 in Chekiang province, in eastern central China. The well was 1.63 metres deep, and had been constructed from lengths of hollowed-out tree trunk. The grey ashy earth inside was filled with pottery sherds that helped to date the well to the late Liang-chu Neolithic culture 良渚文化 (*c.* –2,000 to –1,500).[56] The simple carpentered forms of such wooden wells acted as models for later, more sophisticated structures made of fired ceramic.

Uncontaminated water to drink was an essential aspect of public hygiene, the provision of pure water helping to prevent the spread of waterborne epidemic

[51] Zhang Zizheng *et al.* (1982), pp. 111–16.
[52] *Thien Kung Khai Wu*, ch. 7, p. 1a. Sun & Sun (1966), p. 135.
[53] For example, the section of interconnecting pipes under the South Gate at Phing-liang-thai 平糧台, Huai-yang 淮陽 in eastern Honan province, a Lung-shan site dating to between –2,500 and –1,500. Chang Kwang-Chih (1963, 1986), p. 267; Vainker (1991), p. 23.
[54] The first sanitary ware (*wei-sheng tzhu* 衛生瓷) was made at factories in Thang-shan 唐山 in Hopei province in +1914, see Chao Lien-Chi (1993), p. 1.
[55] Chang Ming-Hua (1990), pp. 67–73.
[56] Lu Yao-Hua & Chu Jui-Ming (1984), pp. 94–5.



Fig. 27 Patterned Neolithic Lung-shan culture drainage pipes from Honan province

diseases. Chinese have always paid attention to provision and circulation of clean water; not only in the palaces of the wealthy, but also in ordinary residential areas. In +1972, a series of interconnecting ceramic water pipes was excavated at Yin-hsü 殷墟 ('waste of Yin'), Hsiao-thun 小屯, An-yang 安陽, site of a late Shang dynasty capital. The extant network of pipes was quite extensive, comprising 28 pipes and running about eight metres north–south, five metres east–west. In its day it must have been part of a much larger system that served this noble city site. The pipes themselves were ribbed, with certain units having flanged side openings to accommodate right-angle pipe joints. They were large, their average dimensions being 42 centimetres long, 21.3 centimetres in diameter, with walls 1.3 centimetres thick, and bore considerable resemblance to present-day water conduits used in China.[57]

Mass production of these functional items for the whole Shang dynasty city at Hsiao-thun must have necessitated specialist workshop manufacture on a large scale. We know from several sources, both archaeological and literary, that separate workshops for various commodities such as bronze vessels, bone-carving and ceramics were established during the Bronze Age, generally outside the walls of

[57] Anon. (1976c), p. 61. Needham & Wang (1965), pp. 127–34, contains a section on conduits and pipes in which some of the material presented here is expounded, and in which comparison with Egyptian, Mesopotamian, Greek and European systems are made.



Fig. 28 Patterned Neolithic Lung-shan culture drainage pipe from Honan province

cities.[58] The late Bronze Age text *Chou Li* ('The Rites of the Chou Dynasty') is quite specific about the role of potters, devoting a whole section to their products, alongside the work of wheelwrights, carriage-builders, bronze-casters, swordsmiths, armourers, embroiderers, jade-carvers, mould-carvers, carpenters and engineers.[59] The work of potters described is, not surprisingly, devoted to the manufacture of ritual vessels such as *pen* 盆, *li* 甗 and *yü* 庾, and does not cover the mundane products of the makers of cisterns and waterpipes.[60] Nevertheless, the work of the latter

[58] For example, at Cheng-chou, where kilns were situated to the south-east of the site and a clay preparation area to the west, see An Chin-Huai (1960), p. 70; Chang Kwang-Chih (1963, 1986), pp. 362–3; and p. 8 of the present volume.

[59] *Chou Li*, chs. 74–86.

[60] *Chou Li*, ch. 81 ('*Thao Jen*'), pp. 12a–13a. Biot (1975), pp. 537–8.

artisans was vital to the health and well-being of the populace in a way that fine vessel manufacture could never be. Perhaps in recognition of this, *Chou Li* does record the great size of the water conduits that ran between the halls of palaces as being 'three feet [*chhih* 尺] in height'.[61]

During the late Bronze Age, ample evidence exists for the continued production of ceramic pipes and water tanks from palace and burial sites. Palace Number 1 in the Chhin dynasty capital of Hsien-yang 咸陽 (a city established by Duke Li 李公 in −350) was excavated during +1973–1975, and yielded subterranean water cisterns that were connected by funnel to a complex network of interlocking ceramic pipes.[62]

There were also five-sided moulded ceramic pipes from the mausoleum of Shih-Huang-Ti, First Emperor of the Chhin 秦始皇帝, that formed part of a huge system used to drain the burial pits.[63] Like other pipes discussed, they were constructed in moulds, from slabs, and were cord-marked on their exterior. Another Chhin dynasty palace, that of Lin-kuang 麟廣 situated about 60 kilometres north of Hsien-yang in Chhun-hua 淳化 county, revealed a subterranean ceramic pipe system. This building was enlarged during the reign of Emperor Wu of the Han dynasty (reigned −140 to −135) to form a palace complex some 45 kilometres in circumference, and during that period was equipped with a luxury water-system that included interlocking ceramic pipe-joints and conduits with decorated ends.[64]

Excavated in the early +1990s, the imperial bathing pool (Hua-Chhih 華清池) near the site of imperial palaces of both Chhin and Han dynasties at Sian yielded quantities of tiles and pipework.[65] Water was conveyed to the pool, and drained out of it, by means of five ceramic water courses. The pipes included plain round-section types that slotted end-to-end, right-angle joints and five-sided pipes. There were also pierced ceramic filters, tiles, and a ceramic-lined well.

More widespread than the construction of city water circulation and drainage systems, and vital to the wellbeing of the populace at large, was the building and maintenance of wells. We have seen that from the beginnings of settled agrarian society in China, wells were made in wood. Later wells were manufactured in stone and ceramic, and their establishment and maintenance was recorded. Access to uncontaminated water sources was often problematic; wells became polluted and frequently needed to be rebuilt. Excavations in China often reveal the presence of whole series of wells in areas close to water sources, each overlapping, overlying or cutting in to earlier constructions.[66]

[61] *Chou Li*, ch. 85 ('*Chhiang Jen*'), p. 34a. Biot (1975), p. 572.
[62] Anon. (1976b), p. 19.
[63] Capon (1982), p. 87, who illustrates large five-sided ceramic pipes used to conduct water away from the subterranean site. Ceramic drainage systems were often massive. A Warring States system drained water from the top of the ramparts of the royal city of the Chao kingdom 趙國 in present-day Hopei. Huge linked sections are on view in the museum at Han-tan 邯鄲.
[64] Zou Zongxu (1991), p. 84.
[65] Anon. (1996b), pp. 17–24.
[66] Anon. (1972c), pp. 39–45.

Hexagram 48
Jing "well"

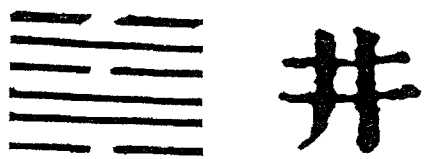


Fig. 29 Hexagram 48 for 'well'

The most revered Chinese classical book, the *I Ching* (The Book of Changes), contains a whole hexagram (number 48) devoted to the symbol for 'well'.

The commentary or 'line statement'[67] on the first *yin* line of the hexagram is a caution on how to recognise polluted wells:[68]

Muddy well – undrinkable muddy [water], an old well where no birds come.

井泥　泥不良舊井無禽.

Where wells were dug was important, and their siting needed to be controlled. The late Chou dynasty political work *Kuan Tzu* (The Writings of Master Kuan), in a section commenting on the internal conduct of states, notes disapprovingly that government was lax where the populace 'drink from mountain streams and dig wells along village lanes'.[69] Conversely, the establishment of a new well could often be occasioned by important events and celebrations, and not only by the risk of disease. *Kuan Tzu* records one occasion on which Duke Huan, ruler of the state of Chhi 齊桓公 during the first half of the –7th century, honoured his Minister of State Kuan Chung 管仲 with a feast. In preparation, the Duke ordered a special guest-house to be preserved where wine would be offered to the minister. Chinese alcohol was often watered, and to this end Duke Huan also dictated that a new well be dug and covered over with planks to keep the water clean.[70]

[67] Shaughnessy (1993a), pp. 216–28.
[68] *I Ching*, hexagram 48, p. 23b.
[69] *Kuan Tzu*, ch. 5 ('*Pa Kuan*'), p. 4b. Rickett (1985), p. 231.
[70] *Kuan Tzu*, ch. 8 ('*Chung Khuang*'), pp. 2a–2b. Rickett (1985), p. 315.



Fig. 30 Ceramic well section from Hsüan-wu 宣武, Peking, Warring States period

Well maintenance is also mentioned in the section on ritual and ceremonial in the *Hou Han Shu* (History of the Later Han Dynasty, +450), which notes that:[71]

When autumn sets in . . . wells are dredged to provide uncontaminated water. When winter comes, flints are drilled to provide purifying smoke from fire.

至立秋 . . . 浚井改水, 日冬至, 鑽燧改火云

A study of ancient brick wells of the -8^{th} to -1^{st} centuries in the Peking area demonstrated that the attention paid to such structures in the literary record was borne out by archaeological excavation.[72]

Hollow Bricks, Strip Bricks and Tiles

The use of unbaked bricks protected by thatched (and later, tiled) roofs has been a major feature of Chinese architecture from its first use in the Neolithic till today. The employment of unfired bricks has far exceeded that of fired brick, which has always been something of a luxury in China.[73] In the loess-lands of northern China, walls were also originally constructed from unbaked, tamped earth, a practice that continues into modern times. Reconstructions of Shang dynasty houses at Hsiao-thun, An-yang, were based on stamped earth foundations and stone pillar bases. Palace reconstructions at the earlier Shang dynasty site of Cheng-chou display similar features.[74] Shang dynasty buildings were long and rectangular, and reconstructions show a simple timber-frame, post-and-beam construction that supported cross-beams placed one on top of the other, in diminishing order of size, to create a pitched roof. The roof was conjectured to be thatched.[75] Mud walls would have been added in to such a construction later, and would not have been load-bearing. Status and function of buildings seem to have been conveyed by size and choice of site. Building size extended laterally, and was based on the extension of a number of *chien* 間 or bays, a spatial formula defined by the upright columns.[76] In all these particulars, buildings of the Shang dynasty in north China set a pattern that has been followed over 3,000 years, down to the present day.

During the Western Chou dynasty new building products were developed for the palaces of the rulers. The seat of Chou power was in the central plain of Shensi province, an area that has been called 'Chou-yüan' (周原, the plains of Chou). There, at workshops and kilns in the area of modern Chao-chia-thai-tshun 趙家台村, were manufactured large, hollow bricks (*c.* 100 (long) × 32 (wide) × 21 (high) centimetres) and smaller, solid, strip bricks. They were fired in kilns separate to those producing

[71] *Hou Han Shu*, *Chih* 5 ('*Li I Chung*'), p. 2b. For gloss on this passage, see Anon. (1972c), p. 44.
[72] Anon. (1972c), pp. 39–45.
[73] See Knapp (2000), pp. 111–16, for a discussion of sun-dried or adobe bricks.
[74] Needham *et al.* (1971), p. 122. Chang Kwang-Chih (1963, 1986), p. 338.
[75] Chang Kwang-Chih (1963, 1986), pp. 324–5. An alternative roof covering would have been woven bamboo or reed matting, as still used on some Chinese boats and sheds. See Needham *et al.* (1971), p. 134, note b.
[76] See Needham *et al.* (1971), pp. 58–144, in particular pp. 61–71, for a discussion of the 'fundamental conception of Chinese architecture'.

pottery vessels, indicating the development of a specialised industry for architectural products.

Tiles

Prior to the early Western Chou dynasty (*c.* −1,050), it is presumed that roofs were thatched with reeds, woven bamboo or straw.[77] The durable nature of compacted loess means that clearly discernible house foundations can be traced, and buildings reconstructed. In the absence of other roof remains, most building reconstructions show thatched roofs.[78] The reconstructed, round, semi-subterranean hut at the excavated Neolithic site of Pan-pho near Sian has a thick layer of mud plastered over the straw. The presence of plank and rafter remains leads archaeologists to hazard some sort of cross-beam structure that supported raised roofs, in the grander buildings. Shang dynasty buildings are also conjectured to have been thatched.

Roofing with ceramic tiles is believed to have started in the early Western Chou period (see pp. 407–9).[79] The tiles were constituted from unglazed, reduction-fired loess, the tough material pioneered during the Neolithic material for vessels. These ceramic tiles gave far greater protection than thatch, both against weather and fire.

Architectural Ceramics in the Chhin Dynasty

In the Sian area of Shensi province, major architectural ceramic finds were made at the sites of Chhin dynasty palaces and tombs. Hsien-yang, as we have seen, became the capital of the state of Chhin in −350, and the imperial capital in −221 when the First Emperor of the Chhin unified China. The imperial palace site at Hsien-yang, which straddled the Wei river 渭河, was the dwelling of the First Emperor. Later changes in the course of the river led to the destruction of the southern end of the palace, but enough remains to demonstrate his enormous wealth and power.[80]

A still more remarkable use of loess occurred in the Chhin dynasty when the material was used to construct more than 7,000 life-size ceramic figures and

[77] Knapp (2000), p. 153, mentions literary reference to Hsia dynasty tiles *c.* −1,561, and also the 'limited use of roof tiles along the ridgelines on compacted roof surfaces during the Shang dynasty'. The authors have not had the chance to verify excavated examples of such early tiles.

[78] For buildings at Pan-pho, including semi-subterranean types, see Knapp (1986), pp. 7–8, figs.1.3, 1.4, 1.5. For buildings at Lung-shan sites that followed Yang-shao and preceded the Bronze Age in the Sian district, see Zou Zongxu (1991), pp. 63–4. Neolithic remains have permitted building reconstructions in many other parts of China, outside the 'yellow earth' area. Knapp (1986), pp. 78–81, points out that until recent decades roofs in the north were thatched with wheat straw, *kao-liang* 高粱 stalks, millet stalks and reeds, while in the south rice straw and wild grasses were used.

[79] The decorative features of tiles at Chou-yüan are mature, and indicate that decorated tiles may well have antecedents in the Shang dynasty; we await archaeological confirmation.

[80] Huge rammed earth fortifications have been found over an area of about 6.5 kilometres (east to west) and 1.5 kilometres (north to south). Zou Zongxu (1991), p. 76.



Fig. 31 One of the burial pits of Shih-Huang-Ti, First Emperor of the Chhin 秦始皇帝, with warriors and horses, +1987

horses – the 'terra-cotta warriors' that were set underground to guard the First Emperor's mausoleum at Li-shan 驪山, in Lin-Thung county 臨潼縣, to the east of Sian. The burial mound of the First Emperor was built just north of the Chhin-ling mountain range, which forms a natural barrier to the southwards spread of the Shensi loess plateau. Neutron activation analysis, carried out in China on the local raw material, has shown that the warriors were made from the same loessic silts in which they were buried.[81] Constructed as a subterranean palace with a wooden supporting structure and paved flooring of fired brick, the mausoleum was protected by figures of men and horses, distributed in four huge pits.[82]

To some extent most of the technical problems involved in making the terra-cotta warriors had been rehearsed more than 1,000 years before, when huge fired loess moulds had been prepared to cast Shang dynasty China's largest known bronze vessel, the *Ssu Mu Wu Fang Ting* 司母毋方鼎, with its height of 133 centimetres and weight of 875 kilograms.[83] The making of the warriors can also be regarded as a development of Warring States brick technology, when hollow bricks, a metre or more in length, were made from fired loess. These square-sectioned bricks

[81] Qin Guangyong *et al.* (1989), pp. 4–5.
[82] For archaeological reports, see Anon. (1975a), pp. 334–9; Anon. (1975b), pp. 1–18, pls. 1–10; Anon. (1978b), pp. 1–19; Anon. (1979b), pp. 1–12.
[83] Bagley (1987), p. 47.

exploited the good engineering principle that a box-girder can be as strong as a solid beam of equivalent size, and thousands of hollow bricks were used in the construction of subterranean northern tombs, particularly in the succeeding Han dynasties. Some of these Warring States clay beams were as substantial in their construction as the separate elements of the warriors themselves. The latter were made in a number of sections, designed to be assembled after firing, namely combined legs and waists, torsos with arms, hands and heads.[84] To make such an enormous number of ceramics it is likely that kilns were established in the vicinity of the mausoleum itself; it was commonplace throughout China's history to establish kilns in the neighbourhood of large-scale building projects, to fire ceramics. To date, kiln remains have not been discovered at Lin-thung.

Loess in Bronze Age Ceramic Vessels

The various making techniques that were developed so successfully for the construction of Chinese bronze-casting moulds, architectural elements and the press-moulding of hollow life-size ceramic sculptures, tended to be specific to those industries. These methods seem to have had little impact on the traditional working methods of most Bronze Age potters, who continued to make their vessels mainly by coiling and throwing. These latter techniques relied on the potters' mental images of the intended forms, combined with skilful freehand construction, rather than on the use of the guides, profiles and hollow moulds that had been developed for the related bronze and funerary sculpture industries. Nonetheless there were occasional exceptions to this principle, particularly the large ceramic funerary vessels excavated in Chhang-phing county 昌平縣, Peking and dated to the Warring States period. These massive unglazed vessels look much like the bronzes of the period, and tend to show the complex profiles, and the squared-off cross-sections, that are typical of Chinese cast-bronze forms.[85]

Use of Loess in the Han Dynasty: Architectural Ceramics and Vessels

By the Han dynasty (−206 to +221), rulers of the southern kingdoms had adopted northern-style architectural components. The kings of Nan-Yüeh 南越 in Kuang-tung province 廣東省, for example, used end-to-end jointed tiles and patterned end-tiles on their palace halls, as excavations during the +1984 to +1990 seasons demonstrated.[86] Similar tile types, many of them inscribed with characters, were employed by the rulers of the Min-Yüeh 閩越 in northern Fukien province.[87]

[84] The process is described in detail in Qu *et al.* (1991), pp. 463–73.

[85] An example of this style of ware can be seen in the National Museum of Chinese History. See Anon. (1988a), National Museum of Chinese History, p. 61, fig. 4–1–4 for an illustration.

[86] Anon. (1991a), pp. 27–37.

[87] Anon. (1985b), pp. 37–47.

During the Han dynasty, in addition to roof tiles, ceramic continued to be used for much larger architectural components. Changes in burial ritual meant that tombs of large numbers of well-to-do people (outside the imperial family) needed to be bigger, to accommodate the performance of burial rites within the chamber itself, and to allow for joint burial of married partners.[88] These changes became dominant after *c.* −140, and were influential through to the end of Eastern Han. In north China, in an area limited to the Central Plain, large tomb chambers were dug out from the loess and lined with a cladding of hollow ceramic slabs.[89] Hollow slabs were very common in Western Han, declined in Eastern Han and eventually died out.[90]

It was early in the Western Han dynasty (−2nd century) that another development in Chinese building materials occurred. This was the manufacture of small, solid bricks. We have seen that as early as the Western Chou dynasty flat strip bricks were made for walls and flooring. The Han brick was smaller, and rectangular or square. Sizes were regulated; the width was half the length, the thickness one-quarter the width. In the Han dynasty small bricks were used for underground drainage systems and tombs, but not yet for city walls. Their use quickly spread from the Central Plain area to all regions, and their functions multiplied.[91]

By the Han dynasties the technique for making pottery vessels in bronze-derived shapes, by pressing loess into porous moulds, was commonplace in northern China. Most examples were made for burial and some show fine and elaborate coloured brushwork. In this case the original models were often painted lacquer vessels which, in the Han dynasties, enjoyed a status far superior to bronze. These expensive lacquer vessels borrowed many forms from the cast-metal tradition.

Han Dynasty Glazed Ceramics

Han ceramics that are painted are usually reduction-fired and reduction-cooled to give ashy-grey grounds for the painted ornament. However, the Han dynasties also saw a marked growth in the practice of lead glazing, the first evidence for which, on pottery vessels, is found in north China late in the Warring States period (late −3rd century).[92] The technique developed gradually in the mid Western Han, when it appeared at sites such as Kuan-chung region 關中地處 in Shensi province and Lo-yang 洛陽 in Honan province.[93] Lead glazing on Chinese burial wares became well established in north China from the +1st century onwards.

[88] Thorp (1987), pp. 28–9.

[89] Large hollow ceramic tomb slabs seem to have been pioneered in Warring States burials, for example, at Erh-li-kang, Cheng-chou, see Needham *et al.* (1971), p. 40.

[90] Wang Zhongshu (1982), pp. 147–8.

[91] Wang Zhongshu (1982), p. 148. One architectural feature that was facilitated by the use of small bricks was the arch.

[92] Wood & Freestone (1995), pp. 16–17.

[93] Wang Zhongshu (1982), p. 143. A rare type of early lead-glazed ware was found on a number of vessels in a late Western Han tomb (dated −73 to +8) at Pao-chi 寶鷄, Shensi province, in +1985. These vessels bear light reddish-brown glazes, enhanced with bands and swirls of copper-green glaze. See Anon. (1988a), National Museum of Chinese History, pp. 38–43, for examples.

The bodies of lead-glazed Han dynasty funerary ceramics are reddish rather than grey and therefore appear, superficially at least, to have been made from different materials from their cold-painted equivalents. Analysis, though, shows clearly that both ware-types were made from loess, but that the lead-glazed ceramics were fired in oxidising rather than in reducing atmospheres. This difference was necessary, as lead glazes tend to turn black and blister in reduction, as lead oxide in a glaze can reduce easily to lead metal, which has a low melting-point of 327°C. When Han dynasty lead glazes are reconstructed with modern materials they tend to mature at about 1,000°C, and this was probably a typical firing temperature for Han lead-glazed wares. As already mentioned, chemical analysis of Han dynasty earthenwares suggests that the potters used more clay-rich loess for their wheel-thrown wares than for their press-moulded ceramics, thereby exploiting the superior plasticity of the more weathered materials.[94]

Loess may also have been an important ingredient in the lead glazes themselves, as subtraction of lead oxide percentages from the Han lead glazes' overall compositions tend to give oxide-balances characteristic of loess.[95] Whether the loess was simply digested from the vessels' surfaces by the attack of a very high lead glazes during firing, or whether loess was deliberately mixed with a lead compound before the glazes were applied, is still an open question.[96] But in either case, its highly siliceous nature would have made it an ideal glaze constituent.

Loess in High-fired Glazes

Although the low melting-point of loess made it unsuitable as a stoneware body-material, its very fusibility was exploited by northern stoneware potters, who used it as the main (and often the sole) ingredient in northern blackware glazes. The earliest examples that have survived probably date from towards the end of the Northern Dynasties (+420 to +589), a time when early high-fired whitewares and celadon wares were also undergoing some important developments in north China.[97] Black glazes of this type reached their zenith in the Thang, Sung and Chin dynasties, and their use became widespread across the loess-lands of the north, where production of black-glazed stoneware has continued to recent times.[98] In some cases more weathered types of loess, of rather lower fusibility, were used for the glazes. These supplied brown rather than black effects such as the famous Red Ting ware glazes of Hopei province (*c.* +12th century), which have a striking similarity to Northern Sung dynasty brown lacquer.

[94] Wood *et al.* (1992), p. 137.
[95] *Ibid.*, pp. 132–3.
[96] Hurst & Freestone (1996), pp. 13–18, give a good account of the former process.
[97] Satō (1981), pp. 48–9.
[98] The authors visited a country blackware kiln near Shen-hou in Honan province in 1985. See Wood (1999), p. 145, for a view of the site.

The fusibility of loess depends largely on its high percentages of alkalis (potassia and soda) and alkaline earths (calcia and magnesia) while its iron oxide contents average at about 6%. During firing, the iron oxides dissolve in the molten glazes at high temperatures to give fine and glossy blacks. The loess material was easily applied to raw (unfired) stoneware clays as its slight plasticity ensured good adherence. When used alone, it probably gave its best glazes at temperatures from about 1,250° to 1,300°C. Temperatures lower than this tended to give dull greenish 'tea dust' effects, from the development of pyroxene-type crystals in the glaze-thickness, during the early stages of cooling.[99]

Loess in Pyrometric Cones

A final example for the versatility of loess in northern ceramics is its use by Chinese potters as temperature indicators within high-temperature kilns. At a number of Northern Sung dynasty kiln sites in both Shensi and Shansi provinces, archaeologists have excavated small cones of fired loess about five centimetres high. These would have been set in ring-shaped supports and placed amongst the wares and saggars in the stoneware and porcelain kilns. During firing they would have been watched by the firemen through spyholes set in the kiln-walls. When the cones melted the kiln-watchers would know that the settings had reached certain temperatures, and would control their kilns accordingly.[100] These pyrometric cones made from loess anticipate a similar invention by the great ceramic chemist, Hermann Seger, by some 800 years.[101]

The Significance of Loess's Use in China

The importance of loess to the Neolithic and Bronze Age people of north China is hard to overstate. This fertile and easily tilled material encouraged the development of China's great agricultural civilisation, and also provided homes for millions of northern farmers for thousands of years.[102] Loess casting-moulds allowed Chinese bronze casters to realise their most ambitious designs, while the pressing of loess into hollow moulds made possible the rapid and successful production of a complete life-size ceramic army in the -3^{rd} century. Long stretches of China's Great Wall were built from fired loess bricks, often applied

[99] Kuang Xuecheng *et al.* (1995), pp. 250–5.

[100] Shui Jisheng (1986), p. 312, fig. 24. The loessic cones may have been used to indicate when kiln operation should change from updraught to cross-draught mode (see pp. 324–5 of this volume).

[101] Seger (1902b), pp. 1010–1027. A progenitor to this principle was developed by Josiah Wedgwood and described in a +1782 paper to the Royal Society, London. Wedgwood (1782), pp. 305–26. Wedgwood used small prismatic bars 2.5 centimetres long made from a controlled ceramic mixture. These could be withdrawn from the kiln, crash-cooled and measured. Their shrinkages represented various time/temperature combinations, and were described in 'degrees Wedgwood'. Such 'coupons' were used by industrial potters and steel-workers until Seger cones became standard in the industry in the late $+19^{th}$ century. William and David Rostoker have calibrated 'degrees Wedgwood' to the centigrade scale. Rostoker & Rostoker (1989), pp. 169–72.

[102] Golany (1992b), p. 151.

Table 6 *Loess, loessic ceramics and loessic glazes of northern China*

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Total
Loess, Wang-chhüan county, Shensi province[a]	63.9	16.9	0.8	5.3	6.0	2.3	2.9	1.6	-.-	0.16	99.9
Loess, Sian, Shensi province[b]	64.9	16.2	0.9	4.6	7.1	2.2	2.4	1.5	-.-	0.2	100.0
Neolithic pot, Hsi-yin, Shansi province[c]	64.0	17.7	0.8	6.3	0.6	2.2	2.5	1.2	0.14	-.-	96.0
Neolithic pot, Pan-pho[d]	67.7	15.9	0.8	5.7	2.6	2.4	3.0	1.8	-.-	0.2	100.1
Shang dynasty earthenware pipe[e]	66.5	17.0	0.8	6.5	2.8	2.0	3.0	1.3	0.1	-.-	100.0
Tripod Han dynasty vessel[f]	66.2	17.9	0.7	5.9	1.6	2.3	3.2	1.8	-.-	0.3	99.9
Unglazed Han dynasty tomb-lintel[g]	68.1	17.2	0.5	4.6	1.2	1.8	2.7	1.5	-.-	0.1	97.7
Chhin dynasty terra-cotta warrior[h]	66.4	16.6	0.7	6.1	2.1	2.3	3.3	1.5	-.-	-.-	99.7
Hopei Sung dynasty temmoku glaze[i]	65.85	16.3	0.95	5.7	5.6	2.4	2.3	1.0	0.07	-.-	100.2
Sung dynasty temmoku glaze[j]	65.6	15.3	0.75	6.7	6.9	2.6	1.8	1.4	0.1	-.-	101.2

[a] Vandiver (1989), p. 14, table 2.
[b] *Ibid.*
[c] Ssu Yung Liang (1930), appendix 2, p. 77.
[d] Freestone *et al.* (1989), p. 261.
[e] Zhang Zizheng *et al.* (1986), p. 112.
[f] Wood *et al.* (1992), p. 138.
[g] *Ibid.*
[h] Zhou Maoyuan (1986), p. 100.
[i] Luo Hongjie (1996), database.
[j] Yang Gen *et al.* (1985), p. 25.

to rammed-loess sub-structures. The material was also used successfully in the north as the basis of both low-temperature and high-temperature glazes. That essentially the same material was used for so many different purposes, many of which appear visually unrelated, becomes apparent when the chemical analyses of these various ceramics are compared with fired samples of natural loess (Table 6).

Unlike China's use of porcelain (which was a totally new material in world ceramic history) the use of loess in China was subtle, efficient and comprehensive, rather than particularly novel. For example, the earliest-known exploitation of loess as a ceramic raw material dates back some 26,000 years, to Dolni Vestonice in the Czech Republic.[103] At this Cro-Magnon Palaeolithic site, some 25 kilometres south of Brno, thousands of small ceramic objects made from fired loess have been found amongst the discarded bones of young mammoth. In terms of ceramics in architecture, primitive bricks and rammed-earth walls were common in Mesopotamia in the –6th millennium. And in the early Old World bronze-casting tradition, fired clay moulds for casting copper alloys have been uncovered from a workshop at Tepe Ghabristan, some 60 kilometres south of Qazvin in Mesopotamia, that is dated to the early Uruk period (*c.* –4,000 to –3,500).[104]

What loess did provide in China was an ideal medium for expressing some of the grander and more ambitious visions of China's ruling classes, whether in bronze-casting, in architecture, or in funerary sculpture. In this respect there was a happy coincidence between what loess could provide and what was asked from it. This was less true of the later ceramic of imperial choice – porcelain. Towards the peak of its firing cycle porcelain may shrink as much as 10% linear, and also warp and distort as gravity acts on the soft 'pyro-plastic' material. The annals of Ching-te-chen are full of protests from its potters at the impossible objects that they were commissioned to make by Peking, with the problems in manufacture increasing with the physical scale of the objects demanded (see pp. 197–213).

The reasons for loess's great success as a ceramic raw material lay mainly in its low clay content and in its low firing temperature, both of which permitted exceptionally low shrinkages in drying and firing. These useful characteristics account for such familiar aspects of Chinese material culture as the freshness of form seen in the large hand-built jars of potters from Pan-pho; the precision and fine detail of Shang dynasty bronze ritual vessels; the ubiquity and reliability of architectural ceramics; and the exceptional uniformity of the terra-cotta warriors. As potters in north China moved from a reliance on loess, towards more plastic and more refractory clays, some of this precision was lost. Nonetheless, despite their greater firing shrinkages, these later materials could withstand far greater kiln temperatures. This in turn improved the strength of the products and, eventually, opened the way for the development of northern high-fired ceramics. After a slow start these highly refractory clays came to replace loess as the basis of north China's ceramic

[103] Vandiver *et al.* (1989), p. 1004.
[104] Moorey (1999), p. 257.

Table 7 *White vessel and black stemmed-cup from Chheng-tzu-yai, Shantung province, late Neolithic*

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Ig. loss	Total
White Neolithic vessel[a]	63.0	29.5	1.5	1.6	0.7	0.8	1.5	0.2	0.03	0.0	1.45	100.3
Black Neolithic cup[b]	63.5	15.2	0.9	6.0	2.65	2.4	2.8	1.6	-.-	0.2	5.4	100.7

[a] Luo Hongjie (1996), database.
[b] Yang Gan *et al.* (1985), p. 25.

production, and their adoption and use represent the next important stage in north China's ceramic history.

NORTHERN WHITEWARES

Loess was the prime ceramic raw material in north China throughout the Neolithic and Bronze Ages, and kept this role until at least the mid 6th century. However, even as early as the Neolithic period, occasional use had been made in the north of a very different clay-type that was entirely opposite to loess in its ceramic nature. This unusual material fired white or buff, compared with the greys, reds and browns of loess-based ceramics, and was used occasionally for making the three-legged, handled pouring vessels known as *kuei* 簋. These trilobate vessels are one of the glories of Neolithic ceramic design, and the potters of Shantung province in particular experimented widely with the proportional possibilities of the legs, bodies, necks, handles and beaked spouts that comprise their complex shapes. Some Neolithic trilobate vessels were entirely hand-built, while others were constructed from separate thrown sections. A single example of Neolithic whiteware that has been analysed in China (a pouring-vessel from Chheng-tzu-yai 城子崖 in Shantung province) shows an entirely novel body-composition for its time (Table 7).

The analysis of the vessel has been compared here with a typical loess-based ceramic, namely a black 'eggshell' stemcup, also from Chheng-tzu-yai. Black thrown stemcups and white trilobate ewers appear in middle Ta-wen-khou culture levels, so they may have been used together. The use of white clay for making such ewers may owe something to the superior resistance that kaolinitic clays can show to thermal shock, for example in the heating and serving of liquids.

In terms of technology, the most obvious difference between the two materials is the low content of iron oxide, 1.6% Fe_2O_3 in the whiteware clay, compared with about 6% in the pottery cup. Another vital feature of the white-burning clay is its low total flux content ($CaO + MgO + K_2O + Na_2O + MnO$) at just over 3%,

compared with about 10% for the loess-based ceramic. These low flux figures mean that the white clay was capable of being fired successfully to at least 1,300°C, a temperature at which ordinary loess would melt into black glass. Nonetheless, despite this potential refractoriness, the original firing-temperature for the *kuei* was probably within the typical firing-range for north Chinese Neolithic earthenware, that is from about 950 to 1,050°C.

Oxide Analyses of Clays and Glazes

The analyses listed in Tables 6 and 7 follow the usual style for describing rocks and clays, and they use an oxide-order familiar from petrographic literature. Oxide analyses of this style are helpful in providing broad images of the ceramics discussed, and they will be used regularly in this section to illustrate China's progress and development in clay design. The method of conducting such analyses, and their limitations, are described in the Preface to this book on p. xlviii, and it should be noted that what an oxide analysis cannot demonstrate is the relative coarseness or fineness of the material under study, nor can it show which minerals were originally present in the raw, unfired, material. In this latter case, however, likely mineralogical proportions can be calculated from an oxide analysis if a general mineralogy for the material has already been established by other methods, such as by the proper mineralogical examination of unfired but related materials. Armed with this kind of knowledge, the percentage analysis of a fired material can be broken down and rebuilt into hypothetical, raw, mineral 'recipe'.

The oxide analyses of minerals used for this kind of work are calculated from the minerals' molecular structures and from their chemical formulae. In kaolinite, for example, the silicon and oxygen atoms make up one layer, with aluminium and oxygen atoms making up the next. A hydrogen-oxygen ('hydroxyl') layer then tops these two layers. The platy crystals that result from these orderly arrangements of atoms are the basis for clay's plasticity, and the material becomes plastic and mobile when free water is added to surround the microscopic crystalline platelets.

The chemical formula for a single kaolinite crystal may be written either as $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$ or as $Al_2Si_2O_5(OH)_4$. The latter, more modern, style gives a better image of how the atoms are arranged, but the former is easier to convert to a percentage-weight oxide mixture. This is managed simply by multiplying the oxide-parts of the molecule by their molecular weights. Thus: $Al_2O_3 \times 102$ gives 102; $2SiO_2 \times 60.1$ gives 120.2; and $2H_2O \times 18$ gives 36. When divided by their total (258.2), and then multiplied by 100, these figures describe pure unfired kaolinite as an oxide mixture. When the raw kaolinite crystal is fired higher than about 650°C the chemically bonded hydroxyl layers (the $2H_2O$ in the formula) are driven away and the fired kaolinite, now known as 'metakaolin' or 'pottery', has the formula $Al_2O_3 \cdot 2SiO_2$ (Table 8).

Table 8 *Kaolinite before and after firing*

Formula	SiO_2	Al_2O_3	H_2O	Others
Raw kaolinite $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$	47.0	39.0	14.0	
Fired kaolinite ('metakaolin') $Al_2O_3 \cdot 2SiO_2$	54.6	45.4		
Shantung *kuei*	63.0	29.5		7.5

When the pouring vessel from Shantung province and the fired kaolinite analysis are compared, a loose similarity in oxide proportions is evident, particularly in the high alumina contents of the two materials. In fact mineralogical calculations (based on the known mineralogies of modern materials from the same area) suggest that this Neolithic clay was probably a mixture of kaolinite, quartz, potassium mica and soda feldspar. Kaolinite and quartz would have been the major minerals present, at levels of about 60% and 24% respectively, with perhaps about 14% of illitic material.[105] But whether the majority of the quartz was a natural impurity in the clay, or whether it was deliberately added as fine sand and as a tempering agent, is still rather difficult to establish. The excavator of the Chheng-tzu-yai site, Li Chi 李濟, certainly believed that sand was added to the white clay, and proposes an elaborate pattern of raw-material usage at this site.[106] The fact that the quartz-sand is obvious in these ceramics may support this theory, as 'natural' sand in clays tends to be silt-grade and difficult to distinguish visually from the clay matrix.

Kaolinitic Clays in North China

With the benefit of hindsight, we can now appreciate that the white vessel from Shantung province was made from a type of clay that came to replace loess as the basis of north Chinese ceramics. These refractory northern clays are usually found beneath the loess cover, and are much earlier than loess in their deposition. They date mainly from the Permo-Carboniferous eras, some 260 million years ago. At the time that these clays were laid down the North China block was enjoying a relatively warm and wet climate by reason of its proximity to the equator. During this period much of its landscape alternated between shallow seas, estuaries, dry land and swamp. Huge carboniferous forests flourished here for millions of years, with dead trees collapsing into the brackish water, where they were preserved first as peat and then with further inundations as coal. The muds on which these forests grew were

[105] Northern kaolinitic clays tend to be relatively simple in their general mineralogies. This is in marked contrast to Chinese loess, which in most samples, as well as abundant quartz, soda feldspar, potash mica, calcite and geothite, can contain the clay minerals, kaolinite, illite, montmorollinite, chlorite and vermiculite. Heavier minerals present in most loess samples include: hypersthene, augite, hornblende, anthophyllite, biotite, tremolite, actinolite, epidote, zoisite, clinozoisite, allanite, wollastonite, apatite, garnet, magnetite, limonite, hematite, spene, zircon, rutile, tourmaline and anatase. Liu Tung Sheng (1988), pp. 88–90, and p. 99.

[106] Li Chi *et al.* (1956), pp. 77–8.

kaolinitic sediments, washed by the rain from distant rocky highlands. The flourishing plant and tree life would have depleted the muds of both fluxes and iron oxides and these refractory argillaceous sediments became preserved beneath the coal as seams of mudstone, shale and clay.

A number of museums in north China (for example, in Cheng-chou, Sian and Peking) hold examples of white-bodied Neolithic ceramics, largely of *kuei* form, and occasionally of impressive size. Subjectively these vessels appear to be made from kaolinitic clays, but apart from the figures cited above the analytical record is still thin on this subject, and it is not impossible that a few of these pale vessels may have been made from unusually calcareous loess. This lack of hard data applies also to the refractories used in the Shang dynasty bronze-casting industry, where one might expect more examples of high-melting clays to occur. Bronze-casting in the Shang dynasty was an outstandingly successful technology, with many examples of very small and very large objects being made. Both extremes of object size required considerable super-heat in the molten casting-alloy (up to 1,230°C in some cases), so efficient refractories must have been used for furnace-linings and smelting crucibles.[107] Likewise the clays used for making models for Shang dynasty bronze-casting moulds needed to be fine, waxy and plastic. This was necessary to supply the kind of detail typical of Shang dynasty ritual vessels. Kaolinitic clays would have been ideal for both purposes.

The role (if any) that kaolinitic clays played in the success of the Shang dynasty bronze industry has still has to be explored but it may be significant that the next important (and, in this case, well-established) use for these clays in north Chinese ceramics is associated with the later capital at An-yang. This was an important site for Shang dynasty bronze-casting, and the city was built near to the foothills of the Thai-hang mountain range 太行山, where the nobility hunted game. High-temperature clays in China tend to be most accessible where the ancient rocks of the Thai-hang mountains rise from the thinning loess, and numerous later sites for whiteware production in north China can be plotted along the eastern margins of this long mountain range as it runs north from Honan through Hopei province, and onwards towards the Great Wall.[108] It is also noticeable, at many of the important early kiln sites in this system, that modern industries such as steel-making, coal-mining, cement-making and refractories-manufacture, have been established in these areas. They exploit the same sedimentary resources of coal, limestone, iron ore and clay.[109]

Shang Dynasty Whitewares

Amongst the thousands of pottery objects excavated at the small hamlet of Hou-chia-chuang 候家庄, some three kilometres north of An-yang, are a few unglazed

[107] Chase (1983), p. 105. Chase gives casting temperatures from 1,010° to 1,232°C for a typical Chinese leaded bronze (Cu 80, Sn 10, Pb 10).
[108] Richards (1986), pp. 67–8.
[109] Wood (1996), p. 54.

pottery vessels made in shapes reminiscent of contemporary bronze or carved bone forms.[110] Their body-materials are white or pale cream, and they are decorated with the kind of detailed carved ornament familiar from Shang dynasty bronze vessels. Most examples have been found in important tombs, for as we discussed on p. 8, whitewares were high-status ceramics. The great archaeologist Li Chi 李濟 even set their importance above that of bronze.[111] Their style is certainly much finer than the contemporary earthenwares, which at this site are largely undecorated, and apart from cord-marks are usually grey. Li Chi divides whitewares from the site into a number of groups such as: 'soft, semi-soft, hard and polished',[112] and notes that they represented only 0.27% of the total ceramic finds.[113] Some compositions for whitewares from An-yang have been established as in Table 9.

The first analysis in the group is of an extremely refractory clay that would have needed kiln temperatures approaching 1,400°C to develop its full ceramic strength. Clays 3, 4 and 5 are less high-firing and would have matured at below 1,300°C. Nonetheless temperatures far lower than these would have been used at An-yang, with some firing estimates being provided by John Pope in +1949, and some by the geologist Nils Sundius in Sweden, who examined two An-yang sherds as part of much larger investigation of Chinese ceramics in +1959.[114]

Pope commissioned Charles Harder of Alfred University to test three sherds of Shang dynasty whiteware, bought in Peking in +1945, and Harder estimated firing temperatures between 950°C and 1,100°C.[115] Sundius found that the two sherds he studied could 'scarcely be scratched with a knife', and that their clay material was 'wholly changed into mullite'. For an equivalent to this kind of transformation Sundius suggested a heating at 1,125°C for ten hours, and proposed that kiln-firings to 1,125°C 'or somewhat higher' had been used for the two whiteware sherds that he had examined. Prolonged soaking at the finishing temperature of a kiln can be the equivalent of an extra 50°C or so of heat, so some of these wares may have been fired to temperatures near to 1,175°C in modern kilns.[116] This approaches the kind of heat used for true stonewares, and is far higher than those suggested for contemporary and earlier northern ceramics, with their firing-limits (*c.* 1,050°C) governed by the low melting-point of loess. No glazes were used on these late Shang dynasty northern whitewares, but some vessels had been burnished before firing by rubbing the half-dry clay with a smooth hard instrument. The effect of burnishing was to flatten and level the platy clay particles on the vessels' surfaces, so that they reflected

[110] One object was an accurate copy in white clay of an ocarina made from bone. Li Chi (1977), p. 219.
[111] *Ibid.*, p. 212.
[112] *Ibid.*, p. 210.
[113] *Ibid.*, p. 202. The rest were: grey 'nearly 90%'; red 'about 6.86%'; hard wares '1.73%'; and black pottery 'about 1.07%'.
[114] Sundius (1959), p. 109.
[115] Pope (1949), p. 52. Pope paid 1,000 Mexican dollars apiece for the sherds.
[116] Ceramic firing is a time/temperature process; longer firings can achieve similar results at slightly lower temperatures to faster firings at higher temperatures (see pp. 525–7 for a full discussion).

Table 9 *Late Shang dynasty whitewares from An-yang*

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Ig. loss	Total
Shang dynasty whiteware 1[a]	49.1	41.2	3.3	1.7	0.6	0.7	0.8	0.2	0.03	0.0	1.9	99.5
Shang dynasty whiteware 2[b]	51.3	40.8	2.2	1.1	1.6	0.5	0.5	0.7	-.-	-.-	1.25	100.0
Shang dynasty whiteware 3[c]	57.2	35.5	0.9	1.2	0.8	0.5	2.3	1.3	-.-	-.-	0.4	100.1
Shang dynasty whiteware 4[d]	57.7	35.1	1.0	1.6	0.8	0.6	2.2	1.0	-.-	-.-	-.-	100.0
Shang dynasty whiteware 5[e]	59.9	34.7	1.0	1.6	0.8	0.5	2.1	1.0	-.-	-.-	-.-	101.6
Fired kaolinite	55.0	45.0										100.0

[a] Luo Hongjie (1996), database.
[b] Yang Gen *et al.* (1985), pp. 30–1.
[c] *Ibid.*, p. 30.
[d] Sundius (1959), pp. 108–9.
[e] Unehare (1932), pp. 41–2, quoted in Pope (1949), p. 61.

a certain amount of light. This gave a smooth surface to the fired clay, and a fine marble-like gloss.

Besides showing that the clays used for Shang dynasty whitewares were highly kaolinitic and refractory, the four analyses above can also be divided into two groups: high-titania and lower-titania. Titanium dioxide has a strong yellowing effect on iron oxide so the higher-titania pair would appear more cream in colour after firing.

In most examples of Shang dynasty whiteware studied so far the silica contents seem close to that of fired kaolinite, which suggests that there was little free silica in the original raw materials and, consequently, a very high proportion of true clay. All this suggests that An-yang whitewares used substantially the same types of raw material as the Neolithic pouring vessel from Chheng-tzu-yai, but employed much lower contents of sand. Whether their appearance at An-yang represents a continuation of a late Lung-shan culture technical tradition, or an influence from bronze-casting technology is still difficult to say.[117] Perhaps the oddest aspect of Shang dynasty whiteware was its failure to establish any substantial northern whiteware tradition and almost eighteen centuries elapsed before such clays again became significant materials in the manufacture of north Chinese ceramics. During this long interval loess remained the prime material for northern potters, and the potentials for high-firing kaolinitic clays were largely ignored.

GLAZED STONEWARES AT AN-YANG

The great mass of ceramic finds from An-yang were red or grey loessic earthenwares, while whitewares appeared as rare inclusions in important tombs. But perhaps even more significant than the whitewares at An-yang were a few examples of true stonewares bearing high-temperature glazes. Glazed stonewares have also been excavated from northern sites that pre-date An-yang. These include the upper strata at Erh-li-kang 二離崗, and the mid Shang dynasty levels at Cheng-chou.[118]

Almost since their discovery in the late +1920s and early +1930s, the possibility has been raised in China that these very early glazed stonewares, found in the ruins of a number of Shang dynasty cities in north China, were actually the productions of stoneware kilns that operated south of the Nan-shan Chhin-ling divide.[119] This opinion was based initially on the style of the wares, but chemical analysis gave further weight to the theory, when the compositions of the northern finds were shown to be extremely similar to contemporary glazed stonewares from southern China (Table 10).

[117] Watson (1991), p. 175, notes that: 'white pottery appears to be absent from the earlier Shang dynasty levels in Honan.'

[118] Deng Zejun & Li Jiazhi (1992), pp. 55–63.

[119] Tadanori Yuba (2001), p. 52, summarises the earliest finds of glazed stoneware in north China thus: 'The earliest examples were unearthed from the Shang dynasty tombs found in Erligang [Erh-li-kang] at Zhengzhou [Cheng-chou] city, Henan [Honan] province. . .'.

Table 10 *Body compositions of Shang dynasty glazed stonewares from northern and southern sites*

Site found	Date	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Ig. loss	Total
North China													
Yüan-chhü 垣曲 (Shansi)[a]	Mid Shang dynasty	77.8	15.5	1.9	0.8	0.14	0.7	2.85	0.3	0.02	0.1	none[b]	100.0
Yüan-chhü (Shansi)[c]	Mid Shang dynasty	79.2	14.45	1.8	0.9	0.1	0.65	2.6	0.2	0.02	0.1	none	100.0
Cheng-chou 鄭州 (Honan)[d]	Mid Shang dynasty	77.6	15.7	1.55	1.0	0.25	0.65	1.8	0.4	0.03	0.06	0.85	99.9
Hsin-cheng 新鄭 (Honan)[e]	Shang dynasty	75.7	16.0	3.5	1.1	0.3	0.9	1.5	0.7	0.06	0.1	0.04	99.9
South China													
Wu-chheng 吳城	Early Shang dynasty	79.4	14.2	1.95	1.1	0.2	0.6	0.9	0.3	0.02	0.25	1.15	100.1
Chiao-shan 角山 (Chiangsi)[f]													
Chiang-shan 江山 (Chekiang)[g]	Shang dynasty	76.6	17.2	1.9	0.9	0.2	0.55	2.3	0.1	0.01	0.2	0.6	100.6
Fei-hsi 肥西 (Anhui)	Shang dynasty	76.9	14.5	2.7	1.05	0.7	0.9	2.3	0.8	0.03	-.-	-.-	99.9

[a] Deng Zejun & Li Jiazhi (1992), p. 58, table 2.
[b] The two Yüan-chhü analyses have been brought to 100%.
[c] Deng Zejun & Li Jiazhi (1992), p. 58, table 2.
[d] Li Jiazhi *et al.* (1992), p. 7, table 1.
[e] *Ibid.*, p. 7.
[f] *Ibid.*, p. 8.
[g] Li Jiazhi *et al.* (1986), p. 57, table 1.

Table 11 *Comparison of stonewares found in Honan and Chekiang provinces*[a]

Site found	Date	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	MnO	Ig. loss	Total
Lo-yang (Honan)	Western Chou	75.15	16.25	1.35	0.9	0.4	0.3	4.3	0.65	0.03	0.95	100.3
Lo-yang (Honan)	Western Chou	72.8	18.65	1.7	0.7	0.3	0.6	3.4	0.8	0.03	1.27	100.3
Shang-yü 上虞 (Chekiang)	Eastern Chou	76.75	16.3	2.0	1.2	0.4	0.25	2.85	0.35	0.07	-.-	100.2

[a] Cheng Zhuhai & Sheng Houxing (1986), pp. 35–9.

Major production sites for early glazed stonewares in the south have so far been found in Chiangsi province, in an area between the Kan river 贛河 and Pho-yang lake 鄱陽湖, and in western Chekiang province. Sites making glazed stoneware then spread throughout south-eastern China, before appearing in Fukien and Kuangtung provinces.[120]

Analysis also suggests that the south–north trade in ceramics continued into the Western Chou period, as glazed stonewares from this time, excavated from Lo-yang in Honan province, show strong compositional and microstructural similarities to Bronze Age glazed stoneware from northern Chekiang (Table 11).[121]

Compositional Differences Between Northern and Southern Stoneware Clays

The most obvious difference between the analyses of Shang dynasty glazed stonewares, and the An-yang whitewares, quoted in Tables 10 and 11, appears in the high levels of silica (SiO_2) that the southern materials contain. A certain amount of this silica is associated with the clays and micas that plasticise the southern bodies, but if this is subtracted from the overall silica totals, 30–40% of free quartz still remains. It is this high proportion of fine silt-grade silica that distinguishes southern stoneware from its northern equivalent, as this fine silica seems natural to southern clays and not a deliberate addition.

Of course, it is possible to take a typical northern stoneware clay, and then add to it large amounts of fine sand as temper. This is a respectable approach to the design of a stoneware body, and its use in north China could have produced analyses similar to those quoted above but, in this case, managed entirely with northern materials. Although there seem no later examples of such a practice in the north, this does not entirely rule out its possible use there in the early Bronze Age.

That such an approach may have been unlikely was shown by a provenance study of Shang dynasty glazed stoneware, using the discriminating analytical technique of Neutron Activation Analysis. This important research was carried out in +1994 by the Peking physicist Chhen Thieh-Mei 陳鉄梅 and his co-workers when they took 93 pottery and porcelain sherds from five Shang dynasty sites and exposed them to NAA (see discussion on pp. 11–12).[122] The single northern site used was Cheng-chou, while the southern sites examined were Phan-lung-chheng 盤龍城 in Hupei province, Chiang-shan in Chekiang province, Chiao-shan in Chiangsi and Wu-chheng in Chiangsi. The best match appeared between Cheng-chou and Wu-chheng, causing the authors to declare that:

[120] Jiang Zanchu & Zhang Bin (1995), p. 18, write: 'During the Western Zhou [Chou] Dynasty . . . proto-porcelain had extended to the whole area of Jiangxi [Chiangsi], Zhejiang [Chekiang], Southern Jiangsu [Chiangsu] and Southern Anhui provinces, but the appearance of proto-porcelain in Fujian [Fukien] and Guangdong [Kuangtung] provinces was a little later.'

[121] Cheng Zhuhai & Sheng Houxing (1986), pp. 35–9.

[122] Chen Tiemei [Chhen Thieh-Mei] *et al.* (1999a), pp. 1003–15, and Chen Tiemei *et al.* (1999b), pp. 20–2.

The NAA results seem to support the Southern China Origin Hypothesis for the first Chinese proto-porcelain wares, and the Wucheng [Wu-chheng] area was the manufacturing centre.

However, some caution may be necessary with this conclusion, as no sites in Chekiang or Anhui provinces were used in the study, and we know that both areas were active in 'proto-porcelain' production in the middle Shang dynasty.

Although accumulating evidence now points to a southern source for the majority of 'northern' glazed stonewares of the Shang and Western Chou periods, the idea that little or no glazed stoneware was made in the north in the Shang dynasty (nor indeed for much of the Bronze Age in north China) is still a difficult concept to absorb. As Yutaka Mino commented:[123]

As it seems unlikely that glazed ceramic wares were transported over great distances during the Shang dynasty, workshops may have been located close to the capital, and to various major Shang dynasty cities even during this early period.

While such a viewpoint seems reasonable, difficulties remain in finding evidence to support the theory. For example, one sherd of Shang dynasty glazed stoneware from An-yang has an analysis reminiscent of glazed An-yang stoneware from the Sui dynasty (*c.* late +6th century), which may be an indication for local production. But even this result is ambiguous, as this same Shang dynasty sherd also has some affinities with some rather anomalous Shang dynasty glazed stonewares from Chekiang province (Table 12).

K. C. Chang notes that the rather dark-bodied glazed stonewares found at An-yang differ visually from those excavated from other Shang dynasty sites in the north.[124] Although the first analysis in the table seems to suggest a separate source for the An-yang glazed stoneware than that of most other examples of glazed Shang dynasty stoneware, just where this particular kiln operated is still unknown.

Bronze Age glazed stonewares have also been found at a Western Chou dynasty site at Fu-feng 扶風 in Shensi province. Some of the glazed stoneware sherds from Fu-feng have been described as 'wasters', which again suggests local manufacture,[125] although the one analysis that exists of the Fu-feng material seems to be classically 'southern' in its oxide composition (Table 13).[126]

Another possible site for locally made glazed stoneware in north China, but very much later in the Bronze Age, is mentioned by Li He when she describes the production of inscribed glazed stonewares from Hsien-yang being made for the Chhin dynasty palace, but compositional data in this case are lacking.[127] In another example Li gives a provenance in Shantung province to a very squat glazed stoneware bottle with a tall narrow neck, now in the Asian Art Museum in San Francisco,

[123] Mino & Tsiang (1986), p. 17.
[124] Chang Kwang-Chih (1980a), p. 151.
[125] Mino & Tsiang (1986), p. 15.
[126] Luo Hongjie (1996), database.
[127] Li He (1996), p. 37.

Table 12 *Body compositions of Shang dynasty and Sui dynasty glazed stonewares from An-yang and a glazed stoneware body from Chiang-shan*

Site found	Date	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	ig. loss	Total
An-yang (Honan)	Shang dynasty[a]	65.3	25.0	3.6	0.5	0.4	0.4	4.3	0.4	trace	-.-	-.-	99.9
An-yang (Honan)	Sui dynasty[b]	68.5	25.3	1.3	1.1	0.2	0.4	2.2	0.2	-.-	-.-	1.05	100.3
Chiang-shan (Chekiang)	Shang dynasty[c]	61.6	28.0	4.4	1.4	0.3	0.6	3.4	0.4	0.03	0.2	0.5	100.8

[a] Luo Hongjie (1996), database.
[b] *Ibid.*
[c] *Ibid.*

Table 13 *Body compositions of glazed stoneware from Fu-feng, Shensi province, Western Chou period*

Site found	Date	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Total
Fu-feng (Shensi)	Western Chou	78.5	14.4	1.5	0.9	0.12	0.3	3.6	0.2	0.01	0.06	99.6

which she dates to the middle to late Western Han dynasty. The provenance is based on a very similar bottle having been excavated at Wu-lien 五蓮 in Shantung province.[128] However Satō places this particular style of vessel to kilns in Anhui and Hunan provinces, in the south of China.[129]

Convincing evidence may yet emerge for some significant production of Bronze Age glazed stoneware in north China but, given the uncertainties that surround the examples quoted above, the feeling on present evidence remains that true glazed stoneware production in north China was rare or non-existent in China's Bronze Age. What is even more remarkable is that this dearth of northern glazed stoneware continued until the end of the +5th century.[130] Before this time, the more significant contributions to glazed stoneware technology in China occurred in the south of the country, and it was the south of China that seems to have supplied the north with its glazed stoneware requirements. This in turn raises the question of how southern glazed stoneware came into being, and once again the essential geology of its ceramics producing areas may provide some useful clues.

The Nature of Southern Stoneware Clay

As described in Part 1, north and south China were once separate tectonic blocks, until their collision in the late Triassic, and their subsequent 'suturing' along the Nan-shan Chhin-ling divide. The early histories of the two areas were therefore separate and distinct. Nowadays much of the landscape of southern China consists of exposed igneous rock, with ample evidence for ancient vulcanism, much of it datable to the Jurassic-Cretaceous period, some 140 million years ago.[131]

One of the most familiar sights across the igneous landscapes of southern China, where most high-fired ceramics are made, are whole hillsides that have been transformed by deep chemical weathering into gritty masses of rotten rock, with the altered materials showing structures and compositions that lie somewhere between rock and clay. In modern times these 'residual' clays are often mined direct for brick-making, as the weathered material has slight plasticity, while its non-plastic fractions act as natural temper to the brick-earth. These abundant mineral-grains (mainly quartz, coarse mica and unreacted feldspar) help speed the drying of bricks, reduce their shrinkage, and also allow safe and fairly rapid firings.

In addition to this primary material, the valleys, paddy fields and river plains of the south are rich in the fine siliceous muds, clays and silts that represent the downwash from this weathered upland material. During water transportation the coarser

[128] *Ibid.*, p. 77 and p. 114.
[129] Satō (1981), pp. 23–4.
[130] Watson (1991), p. 61 writes: 'So far no kilns [producing high-fired glazed stoneware] have been discovered whose activity can be shown to begin before the sixth century, and from this century only one site in the North-east zone has been excavated, at Zibo [Tzu-po 淄博] in central Shandong [Shantung].' However, some +6th-century porcelain kilns, making Hsing wares and Kung-hsien wares respectively, and with their origins in the late +6th century, have been excavated. See also Chen Yaocheng *et al.* (1989a) and Li Jiazhi *et al.* (1986b).
[131] Tregear (1980), p. 10.

mineral-grains settle out, boosting the fine and plastic fractions, and creating smoother and more plastic sedimentary materials.

It is a feature of many surface clays in southern China that they show useful refractoriness, and can be fired safely to at least 1,200°C, reflecting the 'acid' (high-silica) natures of the rocks that produced them. Clays that derive from such rocks are low in the more basic oxides of calcium and magnesium, both of which act as powerful body-fluxes at higher kiln temperatures, and are largely responsible for the poor refractoriness of materials such as loess. Tropical weathering has also raised the melting-points of these clays to some extent, as this process removes some alkaline ions from the rock thus further raising the material's refractoriness.

Current archaeological and scientific evidence indicates that the first ceramics were produced in southern China, at least 1,000 years earlier than those in the north. We have seen how coarse pots from Hsien-jen-tung cave in Chiangsi province were made from *c.* −9,000 (pp. 1–2), and ceramic artefacts from the same era down to *c.* −5,000 have been discovered from sites in the south-western provinces of Kuangsi and Kweichow, and in northern Kuangtung province. The early peoples who made rough, cord-marked pottery in south China often dwelt in limestone caves formed by underground water. Their existence in areas where the later Bronze Age cultures of Shang and Chou had no jurisdiction, is one that continues to be studied. Cultural continuity across southern China and South-east Asia is evident. The interrelationship of southern and northern Neolithic cultures in China itself is of great interest, for although some cultural similarities have been observed, there were also many differences.[132]

In the middle Neolithic (*c.* −5,000 to −3,000) multiple cultures developed south of the Yangtze river, whose pottery varied in colour and quality but whose main distinguishing feature was impressed geometric decoration. In Chiangsu and Chekiang provinces, for example, the Ma-chia-pang 馬家濱, Sung-tse 崧澤 and Ho-mu-tu 河姆渡 cultures made red, brown and black pots, the latter tempered with charcoal. Ho-mu-tu pots were distinctive, being thick and often porous, hand-built, cord-impressed and incised. The Ta-hsi 大溪 and Chhü-chia-ling 屈家嶺 cultures along the middle reaches of the Yangtze made some use of the fast wheel, producing plain, highly polished red, grey and black wares. Sites in Fukien, Kuangtung, Kuangsi, Yunnan and Kweichow provinces made wares whose local characteristics have been carefully described by Chinese archaeologists. Their unifying features were hand construction, use of local raw materials and treatment of surface by polishing or geometric patterning.[133]

A number of these southern Neolithic wares were underfired stonewares that utilised the abundance of superficial deposits of relatively refractory clay to be found in the region. Potters took a long time (more than 7,000 years) to develop their kiln technology to the point where higher-fired, true stoneware could be manufactured.

[132] Chang Kwang-Chih (1963, 1986), pp. 65–8, 95–106.
[133] *Ibid.*, pp. 192–233.

At this point, c. −1,500, kilns in Chekiang province made what archaeologists have called 'primitive porcelain' (*yüan-shih tzhu* 原始瓷), that was coiled but was sometimes finished at the rim on a slow wheel. One such site was Huang-mei-shan 黃梅山 kiln at Hu-chou 湖州.[134]

In the early Bronze Age, ceramics made from these higher-firing clays tend to fall into two groups: unglazed reduction-fired grey wares, often with stamped decoration, and early glazed stonewares. The grey 'stamped' wares contained more iron, at about 4% iron oxides, than the glazed stonewares, with about 2%, but were otherwise compositionally similar. Occasional examples reverse this trend, but most conform to the pattern.[135] Grey, hand-built, reduction-fired, stamped wares pre-date the Shang dynasty glazed wares, but were not replaced by them. Grey and stamped wares continued to be made in south China for most of the Bronze Age, in parallel with the new glazed stonewares, with unchanged compositions, and at substantial levels of output.

It seems likely that the first glazed stonewares of southern China arose from these southern grey wares, most probably because their natural refractoriness allowed kiln temperatures in the late Neolithic gradually to rise until they reached the 1,150–1,200°C range. At these temperatures incandescent wood ash in the draft of the kiln could react with the clays of the wares to produce natural stoneware glazes. From such natural glaze effects Chinese potters seem to have moved rapidly to deliberate glazing with applied wood ashes.[136] On the evidence of the Yüan-chhü 垣曲 finds this vital step, which resulted in the world's first glazed stonewares, seems to have happened in southern China sometime in the middle Shang dynasty.[137]

As southern potters developed their natural 'kiln gloss' into deliberately applied ash-glazes, they must have realised that superior results came from using clays that were lower in iron oxides. These clays were not only more refractory than those used for the ordinary grey-firing wares, but they also gave better colours (mainly greenish-yellows in reduction-firings) with the new ash-glaze compositions. We can therefore speculate that a tradition arose in the south for using stoneware clays that were lower in iron for glazed stoneware production.

We know from Neolithic sites such as Ho-mu-tu in northern Chekiang province that higher-iron and lower-iron refractory clays existed in association, as clays of both types were used for making grey-firing Neolithic pottery as early as the −8th to −1st millennium.[138] In Chiangsi province too, some of China's earliest ceramics at Hsien-jen-tung (−9,000 to −4,000), were made from very underfired (740–840°C) stoneware clays of both the higher- and lower-iron types.[139] In Fukien province (at Chhüan-chou 泉州) both high-iron and lower-iron refractory clays were used for

[134] Anon. (1994), p. 54.
[135] See Li Jiazhi *et al.* (1992), pp. 4–18, for a large database illustrating these trends.
[136] Zhang Fukang (1986b), pp. 40–5.
[137] Deng Zejun & Li Jiazhi (1992), pp. 55–63.
[138] Li Chia-Chih *et al.* (1979), p. 106, table 1.
[139] Wu Rui *et al.* (2002), pp. 2–3, table 1.

late Neolithic wares, and similar choices in refractory materials may well have existed at other sites.[140] It was probably this phenomenon that allowed traditional unglazed grey wares to develop into glazed stonewares in so many regions of southern China, as the lower-iron versions of these unglazed wares show strong compositional similarities to the bodies used for Shang dynasty ash-glazed stonewares (Table 14).

One interesting aspect of this subject is that, although China seems to have made the first glazed stonewares in the world, *unglazed* stonewares had already been developed by potters of northern Mesopotamia in what is now north-east Syria and some neighbouring areas of Iraq and Turkey. These wheel-thrown stonewares are dated to *c.* −2,800 to −2,300, and their compositions are remarkably close to the higher-iron refractory clays used by south Chinese potters for stamped pottery in the later Neolithic. The northern Mesopotamian clays used for making these dark-firing stonewares were entirely different from the fusible calcareous earthenwares typical of most other early Near Eastern ceramics. They were fired to about 1,100°C, often in controlled reducing atmospheres, that gave the wares a rather metallic appearance (Table 15).[141]

What seems to have been absent from the clay resources of north-eastern Syria and associated areas were lower-iron and low-flux siliceous clays of the Chinese type. In retrospect we can see that it was these clays that took China's embryonic stoneware technology to the higher temperature ranges where true stoneware glazes became straightforward to produce.

Development of Southern Glazed Stonewares

We have already described (pp. 11–2, 129–30) how recent analysis of finds from five sites, one in the north and four south of the Yangtze, demonstrated that high-fired greenwares found there probably came from southern kilns. Archaeologists have argued that Chekiang province, in addition to Chiangsi, was likely to have been a source of the earliest greenwares. Future archaeology, and scientific examination, will no doubt determine the case. Certainly the very wide distribution of glazed siliceous stonewares in the Western Chou period, from Peking to Canton, suggests that various areas of manufacture were active. Of known kilns active in the Shang to Western Chou periods, those of mid and eastern Chiangsi and of western Chekiang provinces, were most significant. In addition, high-fired ceramics with either pale or grey bodies and green glazes, stated to have been made locally, have been found at four Shang dynasty sites in Anhui province.[142] By the late Western Chou dynasty, Thun-hsi 屯溪 in Anhui was producing coarse-bodied wares with brown

[140] Li Jiazhi *et al.* (1992), p. 4, table 1.
[141] Schneider (1988), pp. 17–21 (an average of 24 samples).
[142] Hu Yueqian (1994), p. 129.

Table 14 *Neolithic pottery and Shang dynasty 'proto-porcelain' bodies from south China compared*

Site found	Date	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Ig. loss	Total
Neolithic pottery													
Chhüan-chou (Fukien)[a]	Late Neolithic	66.3	21.4	5.9	0.9	0.25	0.7	2.9	0.7	0.04	0.05	0.8	99.9
Chhüan-chou (Fukien)[b]	Late Neolithic	75.2	16.5	1.5	0.6	0.2	0.5	3.0	0.35	0.04	0.06	1.5	99.5
Ho-mu-tu (Chekiang)[c]	Neolithic	68.0	17.9	4.3	0.8	1.7	1.0	2.6	1.1	0.1	2.5	Normalised	100.0
Ho-mu-tu (Chekiang)[d]	Neolithic	70.3	19.85	1.7	0.8	1.7	1.2	2.5	1.6	0.07	0.3	Normalised	100.0
Proto-porcelain wares[e]													
Chhing-chiang 清江 (Chiangsi)	Early Shang dynasty	79.4	14.2	1.95	1.1	0.2	0.6	0.9	0.3	0.02	0.25	1.15	100.1
Chiang-shan (Chekiang)	Shang dynasty	76.7	17.2	1.9	0.9	0.2	0.5	2.3	0.1	0.01	0.2	-.-	100.0
Fei-hsi 肥西 (Anhui)	Shang dynasty	76.9	14.5	2.7	1.05	0.7	0.9	2.3	0.8	0.03	-.-	-.-	99.9

[a] Li Jiazhi *et al.* (1992), p. 4, table 1.
[b] *Ibid.*
[c] Li Chia-Chih *et al.* (1979), p. 106, table 1.
[d] *Ibid.*
[e] Li Jiazhi *et al.* (1992), p. 8, table 1.

Table 15 *–3rd millennium stoneware from northern Mesopotamia and south Chinese Neolithic stamped wares compared*

Site found	Date	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Ig. loss	Total
North Mesopotamian Stoneware[a]	-3^{rd} millennium	67.0	21.5	5.2	1.3	1.6	0.9	2.3	0.1	0.009	0.09	-.-	-.-
Than-shih-shan 疊石 山, Fukien[b]	Late Neolithic	65.1	22.7	5.4	0.9	0.48	0.7	2.5	0.5	0.05	0.2	2.1	100.5
Nan-an 南安, Fukien[c]	Late Neolithic	66.3	21.4	5.9	0.9	0.25	0.7	2.9	0.7	0.05	0.04	0.79	99.9

[a] *Ibid.*, p. 20., table 1, average of 54 samples.
[b] Li Jiazhi *et al.* (1992), p. 4, table 1.
[c] *Ibid.*

flaky glaze and finer, whitish-bodied greenwares. Excavated burials in Chiangsu, Fukien and Kuangtung provinces also yielded glazed wares.[143]

From the middle Western Chou period (–9th century) the technology of glazed stoneware manufacture gradually improved, as demand for high-quality ceramics for ritual and burial increased. This was actuated by suggested revisions to ceremonial practice that led to the adoption of new vessel types.[144] Ceramics were made in a variety of bronze forms, including those used for ritual consumption of food and drink, bells and weights. Eastern central China was the principal region for development, in particular northern and eastern Chekiang province.

Far fewer hard-fired glazed ceramics seem to have been exported from south to north China during the later Western Chou and Spring and Autumn periods (–8th to –5th centuries), although this does not seem to coincide with any reduction in glazed stoneware production in the south.[145]

In the Warring States period (–5th to –3rd centuries) the state of Yüeh 越國 established control of the centre of greenware manufacture in eastern central China, though ceramics with incipient glazes continued to be produced in the far south.[146] When the state of Chhu 楚國 defeated Yüeh in the –3rd century widespread disruption ensued. It was at this time that technology spread into Hunan province, the traditional territory of the Chhu state, and further south as far as Kuangtung province. From then on a unified tradition of southern glazed greenwares developed, though local styles continued to hold sway. Two major regions may be discerned; an eastern-central region comprising the provinces of Chekiang, Chiangsi, Hupei, Anhui and Chiangsu; and a southern region embracing Kuangsi, Kuangtung, Fukien and Hunan.[147] In general terms, ceramics from the former region, and particularly those from Chekiang province, were of higher quality. There was less reliance on bronze forms, and many new shapes and decorations started to appear. By the Western Han dynasty vessels glazed on the upper half of the body and inside the mouth with a superior form of green glaze had developed. The manner in which the glaze pools above lugs and other protuberances suggests that it was applied in powder form, sifted from above on to the upper half of the body.

Ceramics of this type excavated from Han dynasty tombs in Sian and Lo-yang indicate that such vessels were probably transported to north China with foodstuffs inside them and were later buried with their owners. Sherds of similar wares have been excavated from kilns at Ning-po 寧波, Wen-chou 溫州 and Shang-yü 上虞 in Chekiang province.[148]

[143] Yin Ti-Fei (1959), pp. 81–2. Mino & Tsiang (1986), p. 32.
[144] Rawson (1990), pp. 108–9.
[145] Yuba (2001), pp. 58–60.
[146] Yeh Wen-Chheng (1994), p. 120.
[147] Mino & Tsiang (1986), p. 16.
[148] Vainker (1991), pp. 47–8.



Fig. 32 Model of a ceramic bell, stoneware with traces of ash-glaze, from Chen-hai 鎮海 in Chekiang province, Spring and Autumn period



Fig. 33 Western Han vase in bronze form *hu* 壺, with glaze ash gathered on the shoulder

Greenware manufacture in north-eastern Chekiang province developed to the level that, by the Eastern Han dynasty, wares of recognisable Yüeh type were being made. Yüeh ware 越窯 is the generic term for a type of high-quality ceramic with refined glaze, made in Chekiang from the Han period to the +11th century.[149] From +220 to +280 the important eastern-central ceramic region was under control of the kingdom of Wu 吳國. Shang-yü in north-eastern Chekiang province took a commanding lead as a manufacturing centre, establishing more than 60 kilns in the +3rd century. An indication that high-quality ceramic wares were replacing lacquer and bronze for ritual and burial is provided by the earliest inscribed vessel yet recovered. A celadon urinal (*hu-tzu* 虎子) from the tomb of Chao Shih-Kang 趙士岡 in Nanking bore an inscription mentioning the date (+251), the name of the potter who made it and an assessment of its quality. The inscription was similar in form to those found on Han dynasty official lacquer ware, and the fact that the potter was honoured with the title 'Master' (*shih* 師) indicates a hierarchical system at the kilns involving supervising officials.[150] When the Eastern Chin swept down from northern China and established their capital at Nanking in +317, Shang-yü declined and other pottery centres in Chekiang, Chiangsi and Hunan provinces competed for business.[151]

During the late Warring States period and Han dynasties glazed stonewares tended to be glazed only on their upper bodies and generally show a more utilitarian character. Unglazed grey stonewares, often decorated by stamping, also became particularly abundant in the south at this time. By the Six Dynasties period, some 2,000 years after their first appearance in China, ash-glazed stonewares at last became the dominant southern stoneware material, to the extent that they displaced bronze and lacquer vessels for many uses.

ROCK OR CLAY?

How southern potters prepared their materials for stoneware-making is still debated, but there is a tendency in Chinese writings to refer to the use of 'porcelain stone' as the prime southern material, rather than conventional clay.[152] However, *tzhu* 瓷 describes a ceramic that is dense and resonant when fired, rather than white and translucent, and 'stone' does not necessarily imply a tough and hard rock.[153] The term may therefore imply some fairly direct use of the weathered rocks from which most southern clays derive. These crumbly rocks can easily be crushed, and their finer fractions extracted and retained by washing. By allowing this finer

[149] For a discussion on different interpretations of the term Yüeh ware see Tregear (1976), p. 1; Ho Chui-Mei (1994b), p. 104. For sherds excavated from eight kilns in Chekiang province, of Eastern Han to Northern Sung dynasty date, see Hughes-Stanton & Kerr (1980), nos. 1–92.

[150] The inscription read *Chhih-Wu shih-ssu nien hui-chi Shang-yü shih Yüan I tso* 赤烏十四年會稽上虞師袁宜作 'Made by Master Yüan I and quality-checked at Shang-yü in the 14th year of the Chhih-Wu reign (+251)'. Anon. (1955), p. 97.

[151] Mino & Tsiang (1986), p. 18.

[152] Guo Yanyi (1987), p. 5.

[153] The Chinese term *tzhu* is discussed on p. 11.

Table 16 *Compositional changes in Wu-kuei-shan 烏龜 clay, Hang-chou 杭洲, during processing*

State	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	MnO	Ig. loss	Total
Raw, unfired	73.6	17.0	1.0	0.9	0.15	0.25	1.8	0.2	<0.01	5.5	100.4
Raw, fired	77.5	17.9	1.1	1.0	0.16	0.26	1.9	0.2	<0.01	none	100.02
Washed, unfired	68.9	20.9	1.6	1.3	0.25	0.5	3.05	0.5	<0.02	10.1	107.1
Washed, fired	77.1	21.5	1.6	1.3	0.3	0.5	3.1	0.5	<0.02	none	105.9

Table 17 *Siliceous earthenwares and stonewares of southern China, Neolithic period to Sung dynasties*

Date	Kin site	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	Province
Late Neolithic[a]	Chhüan-chou	75.2	16.5	0.6	1.5	0.2	0.5	3.0	0.35	Fukien
Mid Shang dynasty[b]	Wu-chheng	73.9	18.1	1.2	2.6	0.2	0.65	1.7	0.3	Chiangsi
Western Chou dynasty[c]	Shih-men Ta-mai-shan 石門大麥山	76.1	17.4	1.0	1.9	0.25	0.3	2.9	0.5	Chekiang
Eastern Chou dynasty[d]	I-hsing 宜興	75.7	16.2	1.0	2.2	0.3	0.5	2.1	0.7	Chiangsu
Thang dynasty[e]	Chhang-sha 長沙	72.9	19.7	0.8	1.6	0.1	0.6	3.05	0.15	Hunan
Thang dynasty[f]	Chhiung-lai 邛崍	75.4	16.1	1.0	3.2	0.25	0.9	2.1	0.4	Szechuan
Northern Sung dynasty[g]	Yung-fu 永福	73.9	19.2	1.1	1.9	0.5	0.8	2.1	0.3	Kuangsi
Northern Sung dynasty[h]	Hui-chou 惠州	72.4	21.8	1.1	1.9	0.5	0.8	2.1	0.3	Kuangtung

[a] Li Jiazhi *et al.* (1992), p. 4, table 1.
[b] *Ibid.*, p. 7, table 1.
[c] Li Jiazhi *et al.* (1986), p. 57, table 1.
[d] Luo Hongjie (1996), database.
[e] Zhang Fukang (1987), p. 90, table 1.
[f] Zhang Fukang (1989), p. 63, table 1.
[g] Luo Hongjie (1996), database.
[h] *Ibid.*

material to settle, and then to stiffen to a plastic mass, the weathered rock can be quickly processed into usable clay, thereby mimicking a process that might in nature take thousands of years to complete.

One advantage of this approach in southern China is that secondary clays are often deposited many miles from their highland primary sources, and in some of the more mountainous areas of the south usable secondary clays are rare. Nonetheless, by refining the local weathered rocks *in situ*, stoneware clays could be processed direct from local primary materials, a technique that also generated large amounts of mineral grit as by-products of clay refining. This gritty material was often used on the floors of kilns to level saggers and ware-supports, and also as fillers in various types of refractory brick. Although clay preparation from weathered rock speeds the natural process dramatically, the end result can be much the same as natural secondary clay and this can make it difficult to decide whether a primary or secondary clay has been used to create a particular southern stoneware body, although the presence of freshwater shell in the clay may sometimes provide a clue.[154] Nonetheless it seems likely that both primary and secondary materials were used extensively across southern China as raw materials for making both early and later glazed stonewares.

A good image of how processing can change clays of this type was provided by Zhou Shaohua and Chen Quanqing [Chou Shao-Hua and Chhen Chhüan-Chhing 周少華, 陳全慶] in +1992. Their figures suggest that processing results in some loss of coarse quartz (decreased silica), and an enhancement of the plastic micaceous clay components in the clay (indicated by increased potassium and iron oxides and by raised ignition losses) (Table 16).[155]

What can also be demonstrated clearly by chemical analysis is the remarkable continuity in glazed stoneware composition that operated in south China from the Shang dynasty until at least the +10th century. This unusual compositional consistency encompassed a huge geographical area, took in thousands of kiln sites, and some 3,000 years of production. This remarkably ubiquitous distribution of very similar stoneware materials has made southern siliceous stoneware one of the four great clay-types of China, and the backbone of early Chinese glazed stoneware technology (Table 17).

[154] Chen Xianqiu *et al.* (1992a), pp. 34–7. Although the wares described in this paper are Neolithic earthenwares (*c.* −4,000) some examples are potential low-stoneware materials.

[155] Zhou Shaohua & Chen Quanqing (1992), p. 370, table 2.

PORCELAIN: DEVELOPMENTS IN NORTH CHINA

In the +5th century high-fired glazed stoneware appeared in north China, with rapid growth ensuing in the +6th century. This material was followed in the late +6th to early +7th century by true white porcelains. As northern porcelains seem to have been developed from northern stonewares, it is the stoneware material that will be considered first.

THE GROWTH OF GLAZED STONEWARE IN NORTH CHINA

Large quantities of glazed wares had been made in north China before the +5th century, but these used lead glazes applied to low-firing loessic clays. The main function for the lead-glazed earthenwares was as burial wares in the Han dynasties, and they saw little use as everyday ceramics. From the +4th to the first half of the +5th century, lead glazing in north China was at a very low ebb, but its revival in the later +5th century is shown by the substantial finds of lead-glazed wares (vessels, figures and glazed roof tiles) in a tomb closed in +484, belonging to an aristocrat called Ssu-Ma Chin-Lung 司馬金龍 at Shih-chia-chai 石家寨 village south-east of Ta-thung 大同, Shansi province.[156] In addition to lead-glazed wares, findings from this tomb, and from the later tomb of Su-Ma Chin-Lung's third son, Ssu-Ma Yüeh 司馬越 (*d.* +508), included some high-fired glazed wares, although whether these were of local manufacture is still a question. Shortly after this in the early +6th century, however, the contents of other excavated tombs indicated that high-fired glazed ware was being made locally. Northern Wei dynasty tombs provided the earliest evidence, though no kilns have been discovered to date.[157]

Wares using forms borrowed and adapted from the south were common, and these included tall cockerel-headed ewers and squat jars with squared lugs, tall necks and wide flaring rims. Tea-bowls with yellow and dark-brown glaze were also seen, while celadons were found from the middle of the +6th century. In Honan province, mid +6th century kilns have been identified at An-yang,[158] while in the Northern Chhi dynasty (+550–577) kilns at Kung-hsien 鞏縣 made light-coloured stonewares as well as brown, black and light-green ceramics with fine glaze-crackle.[159] A very ornate, lotus-petalled style was made from this time until the Sui dynasty.[160]

[156] Anon. (1972d), pp. 20–33.
[157] Mino & Tsiang (1986), p. 18. A Northern Wei dynasty tomb of +520 in Shansi province yielded significant glazed stonewares, see *ibid.*, p. 102.
[158] Honan archaeologist Yang Ai-Ling 楊愛玲 considers that the Hsiang-chou kilns 相州窯 at An-yang were active from the late Northern Dynasties to the Sui Dynasty. Yang Ai-Ling (2002), pp. 70–1.
[159] Watson (1991), pp. 63–4, 37.
[160] Mino & Tsiang (1986), p. 19.



Fig. 34 Two elaborate, high-fired vases from Tzu-po, with the remains of celadon glaze that has been abraded through burial

The only other kilns yet found were at Tzu-po 淄博 in Shantung, that also started production of greenware in the +6th century.[161]

The northern stoneware clays were pale, porous and rather coarse, compared with the smooth grey and vitreous materials of southern China. The northern glazes tended to fire pale green or straw-coloured, and were usually densely crazed. Nonetheless early northern stoneware vessels embody a powerful presence, particularly massive vessels in bronze forms, encrusted with applied moulding and embellished by deep carving. Such tall and elaborate vessels date mostly to the Northern Chhi dynasty, and often bear olive-green stoneware glazes that reach to the vessels' feet.

It is difficult to discuss the growth of northern high-fired glazed stoneware without first trying to understand the reasons for its long absence in the area. There are still problems with this subject, but it may be useful here to rehearse some reasons behind the success of the southern stoneware industry, as many factors that operated in south China were either different or entirely absent from the north.

[161] Watson (1991), p. 61.

Possible Contributing Factors to the Success of Southern Glazed Stoneware

Southern glazed stonewares seem to have evolved naturally from late Neolithic stamped wares. These were often made from natural stoneware clays, albeit somewhat underfired. The temperatures needed to mature these largely dark-firing clays were in the low stoneware range, for example, 1,150–1,220°C and therefore not too difficult to reach in early southern kilns as their designs and their use became more efficient. These southern clays were either sedimentary surface clays, or were processed from exposed and weathered igneous rocks, so were quite accessible to the potters. Also the siliceous clays, typical of these southern wares, made excellent glazes with the application of wood ash, and this became a simple and straightforward technology for the potters to exploit.

In north China, by contrast, common surface clays were largely fusible and loessic, and unsuitable bases for stoneware technology. True stoneware clays of the north tended to be more deeply buried, due to their much greater age of deposition, and mainly accessible where the loess beds thinned, such as at the margins of mountains, or in the banks of deeper rivers. Even when identified and exploited these ancient clays were highly refractory and needed substantial kiln temperatures to mature them. To these problems can be added the high-alumina and low-flux natures of northern clays. Aluminous clays of this type would have given poor-quality glazes when mixed with wood ashes, the standard southern approach to glaze-creation. Thus a combination of geological and technical factors may have inhibited the development of true glazed stoneware in the north. No doubt better communication with southern potters could have accelerated this process but, as Mino and Tsiang write:[162]

> After 386, because north China was ruled in large part by various non-Chinese tribal people for two hundred years, until the reunification under the Sui dynasty, there was little economic or cultural contact between it and the East-central or southern regions.

For some or all of these reasons, northern glazed stonewares were slow to start production but, when they did, the northern potters turned again to the refractory clays, first used for some trilobate whiteware ewers in the late Neolithic, and for unglazed carved stonewares in the late Shang period. It seems that an area of northern Honan and southern Hopei, within a 200-mile radius of An-yang, was one district that provided suitable materials for this developing northern stoneware industry, where similar refractory clays to the ancient whitewares were used, but now enhanced with true stoneware glazes (Table 18).

[162] Mino & Tsiang (1986), p. 18.

Table 18 *Neolithic Shang and Sui dynasty refractory clays from north China compared*

Site found	Province	Date	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	MnO	Ig. loss	Total
Chieng-tzu-yai 城子崖[a]	Shantung	Late Neolithic	63.0	29.5	1.5	1.6	0.7	0.8	1.5	0.2	0.03	1.45	100.3
An-yang[b]	Honan	Shang	57.2	35.5	1.2	0.9	0.8	0.5	2.3	1.3	---	0.4	100.1
An-yang[c]	Honan	Shang	52.7	35.1	1.6	1.0	0.8	0.6	2.2	1.05	---	---	100.1
An-yang[d]	Honan	Sui	68.3	25.3	0.3	1.1	0.2	0.4	3.2	0.2	---	1.05	100.3

[a] Luo Hongjie (1996), database.
[b] Yang Gen *et al.* (1985), p. 30.
[c] *Ibid.*
[d] Luo Hongjie (1996), database.

CHINESE PORCELAIN

It was against this background of stoneware revival in north China that true porcelain came into being. Porcelain is China's most significant contribution to world ceramics, to the extent that 'porcelain' and 'china' are synonymous in the English-speaking world, and in Arabic too the word for porcelain '*faghfuri*' refers to its country of origin.[163] As is well known, much of the course of world ceramic history has been driven by attempts by potters beyond China to understand this material, or at least to copy it superficially with local resources.

It is sometimes stated that porcelain was 'invented' in China, which raises an image of countless tests with likely and unlikely ingredients, before an event occurred that created the ideal material – rather as happened in Europe in the late +17th and early +18th centuries (see Part 7 of this volume). However, a more accurate description for the process might be 'discovered', particularly as the material seems already to have existed in nature in north China, largely in the form that it came to be used by the potters. In fact 'emerged' might be an even better term, as porcelain seems gradually to have appeared in China as northern potters tested whiter and whiter ceramic materials, and coaxed their kilns to higher temperatures to mature them. These clays were encountered as potters of the Northern Chhi dynasty explored north China's Permo-Carboniferous geology, in areas where its resources were most accessible, particularly on the eastern margins of the Thai-hang mountain range.

The natural porcelain clays of north China are therefore white-firing secondary kaolins, and are near relations to the paler types of northern stoneware. Indeed, there seems to be a continuum between these materials that can sometimes make it difficult to judge just where stoneware ends and where porcelain begins. Many of these whiter clays needed greater kiln temperatures than the stonewares to achieve

[163] *Faghfuri* is an Arabic expression derived from *faghfur* 'Emperor of China'. It is adapted from a Middle Persian expression *baghpur* 'Son of God', and was used to mean porcelain in Persian and Ottoman texts, pers. comm. Tim Stanley.

suitable fired strengths and, in a few cases, a modest degree of translucency. Very early northern whitewares tend to bear glazes (usually oxidised lime glazes) that are somewhat overfired, while the clays beneath were still approaching their best firing temperatures. In the late Sui to early Thang period this resulted in a range of wares with glassy and somewhat glue-like crackled glazes on white chalky-looking clays, often with visible sand additions. In some examples the body-materials were potential porcelains, but the glazes were lower firing than the clays they were used to cover.

SLIPS

One possible route to northern porcelain may have been through the use of white slips, which are suspensions of clay in water into which pots can be dipped to improve their fired colours. White slips tend to be made from the finest clays available and were probably used in the mid +6th century to enhance a few northern stonewares,[164] and it would have been a short step from this technique to throw or to mould ceramics from the slip-material itself. Certainly, by the time that the tomb of Fan Tshui 範粹 at An-yang was closed in +575, true white-firing clays were being used for entire objects, as seven examples of whitewares with high-temperature glazes have been excavated from this site.[165] Watson believed that these wares could have been made at kilns in the vicinity of An-yang,[166] and Yang Ai-Ling suggests that they come from the local Hsiang-chou kilns.[167] Kilns there made very fine whitewares, and were much nearer than the better-known kilns in Kung-hsien, some 320 kilometres away to the south-west.[168]

Contemporary with the tomb of Fan Tshui, and also in Honan province, is a burial site at Phu-yang 濮陽, some 100 miles east of An-yang.[169] This richly accoutred tomb is dated to +576 and is of particular interest for yielding vessels with lead glazes applied to whiteware bodies. Lead-glazed whitewares mark an important break with loess as the standard body-material for northern lead-glazed earthenwares. Although rather soft at earthenware temperatures, these new white clays supplied pure and bright colours to the transparent lead glazes that covered them, typically appearing as straw-coloured glazes augmented with copper green.[170]

[164] Watson (1991), p. 36, discussing wares from a Northern Chhi dynasty tomb notes: 'at other Henan [Honan] sites it can be shown that a clear glaze was put over a pure white body, or that body of inferior colour was given a white slip before glazing . . . and it is possible that this method was followed on some of [these] pieces.'

[165] Anon. (1972b), pp. 47–57; Yang Ai-Ling (2002), pp. 70–1.

[166] Watson (1984), p. 58.

[167] Yang Ai-Ling (2002), pp. 72–3.

[168] The museum at An-yang, visited by the authors in +1997, displays sets of +6th-century fine whitewares from local tombs, and comparable sherd material from local kiln sites.

[169] Satō (1978), p. 57.

[170] See Yang Gen *et al.* (1985), p. 82, with caption on p. 176.



Fig. 35 Whiteware jar with copper-green stripes from tomb of Fan-Tshui at An-yang, *c.* +575

This combination of underfired kaolinitic clay and superimposed coloured lead glazes anticipates the Thang dynasty *san-tshai* 三彩 technique by perhaps 100 years.[171] It also began a trend in China for the use of high-temperature clays as bodies for earthenware glazes; an approach that eventually became standard practice across the country. In mortuary wares these clays tended to be low-fired, as everyday strength was not an issue, but export and domestic wares were often given a hard biscuit-firing to toughen them, followed by a low-temperature firing (*c.* 1,000°C) to mature their glazes.[172] However, this hard-biscuit/soft-glaze approach was a later Thang dynasty refinement and the pioneer lead-glazed whitewares at An-yang and Phu-yang seem to have been fired to much the same temperatures as the glazes.

[171] *San-tshai* means 'three-coloured' in Chinese and is the term most often used to describe wares decorated with lead glazes in several shades. The most common colours were straw (i.e. practically colourless), amber and green, but blue, red, white and black were also employed. The term *san-tshai* seems a modern description, coined when thousands of lead-glazed Thang burial wares were uncovered by railway construction in northern China in the +1920s. Most of the wares found at the time were glazed in straw, amber and green, and the *san-tshai* description is now well established in the literature. One railway engineer of that time was Orvar Karlbeck, who worked on the Tientsin-Nanking 天津-南京 line from +1907 to +1927, when he collected many Thang dynasty ceramics. Karlbeck returned to China on various occasions between +1930 and +1935, mainly on collecting missions. He described a subterranean workshop making imitation Thang dynasty *san-tshai* wares near Lo-yang in the +1930s, see Karlbeck (1957), pp. 106–7.

[172] Rawson *et al.* (1989), p. 49.

KUNG-HSIEN 鞏縣

This early connection between high-fired whitewares and the production of lead-glazed earthenwares for burial, and later for export, saw its greatest development at Kung-hsien in northern Honan province. Kung-hsien was one of the earliest porcelain sites, where C^{14} dating of kiln firebox charcoal has yielded a date of +575.[173] Manufacture of pots in the region started around that time, with important developments occurring in the Thang dynasty when white porcelain was made as imperial tribute ware during the Khai-Yüan reign period (+713–41). Investigations at Kung-hsien in +1957 by two men who were to make major reputations in the field of Chinese ceramics, Feng Hsien-Ming 馮先銘 and Li Hui-Ping 李輝柄, revealed three kiln sites. All three (Hsiao-huang-yeh 小黃冶, Pai-ho-hsiang 白河鄉, and the largest in scale, Thieh-chiang-lu-tshun 鐵匠爐村) yielded sherds of white porcelain as a major product. The two smaller kilns also made *san-tshai*.[174]

San-tshai kilns at Kung-hsien supplied the late Thang capital of Lo-yang with enormous quantities of lead-glazed funerary wares, in addition to its regular whiteware production. Chemical analysis of Kung-hsien *san-tshai* ware clays has shown that they were made from virtually the same materials as the local high-fired whitewares (Table 19).

Iron and titanium oxides are the main discolourants of porcelain clays and the levels at which these oxides occur in Kung-hsien whitewares gave rather cream and non-translucent materials that can be placed on the 'white stoneware' side of true porcelain. In composition they resemble the clays used in Shantung province for Neolithic whitewares (see above), although by the +6th century they were being fired to some 200–300°C higher. The simultaneous use of similar clays for such different wares shows the versatility of northern secondary kaolins, though the material was perhaps less protean in its potential than loess.

In addition to this typical northern whiteware material, there is an interesting sub-type of Kung-hsien whiteware that shows higher alumina levels, lower colouring oxide impurities, and also unusually high levels of alkalis. These wares are whiter, tougher and more prone to translucency than typical Kung-hsien whitewares (Table 20).

In terms of mineralogy this small group of Kung-hsien wares are unusual in that they seem to have been natural mixtures of kaolinite and mica (probably the hydromica known as illite) with very little free quartz. Kaolinite and mica are both plastic minerals, so the micaceous clays would have been highly workable when raw, but also unusually high-shrinking and vitreous when fired, due to the fluxing potential of potassium mica. Nonetheless, these were probably still natural clays, rather than contrived compositions, as similar kaolinite-mica mixtures can occur in New South Wales and Hungary, amongst other places.[175]

[173] Li Jiazhi *et al.* (1986b), p. 129.
[174] Feng Hsien-Ming (1959), pp. 56–8; Hughes-Stanton & Kerr (1980), pp. 80–1.
[175] Anderson (1982), p. 47 and p. 48, table 2. Mattyasovszky-Zsolnay (1946), pp. 254–60.

Table 19 *Analyses of Kung-hsien* san-tshai *and whiteware bodies: Thang dynasty*

Site found	Date	Type	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	P_2O_5		
Kung-hsien	Sui-Thang	whiteware[a]	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	P_2O_5	Ig. loss	Total
Kung-hsien	Sui-Thang	whiteware[b]	67.7	26.8	0.6	1.3	0.4	0.4	2.1	0.5	0.04	0.8	100.6
Kung-hsien	Sui-Thang	whiteware[c]	63.1	30.3	1.3	1.2	0.5	0.5	2.0	0.5	0.06	0.9	100.4
Kung-hsien	Thang	*san-tshai*[d]	66.3	28.0	1.0	1.3	0.3	0.45	2.3	0.45	0.04	0.3	100.4
Kung-hsien	Thang	*san-tshai*[e]	66.9	26.6	0.7	1.2	0.2	0.4	2.15	0.4	-.-	-.-	98.6
Chheng-tzu-yai, Shantung	late Neolithic[f]	whiteware (unglazed)	64.5	27.1	1.2	1.45	0.9	0.4	2.1	0.4	-.-	-.-	98.1

[a] Li Jiazhi *et al.* (1986b), p. 130.
[b] *Ibid.*, p. 130.
[c] *Ibid.*
[d] Li Zhiyan & Zhang Fukang (1986), p. 69.
[e] *Ibid.*
[f] Luo Hongjie (1996), database.

Table 20 *Analyses of higher alkaline Kung-hsien whiteware bodies: Thang dynasty*

Site found	Date	Type	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	P_2O_5	Ig. loss	Total
Kung-hsien	Sui-Thang	whiteware[a]	53.4	37.15	0.65	0.8	0.55	0.4	5.0	2.1	0.04	0.3	100.4
Kung-hsien	Sui-Thang	whiteware[b]	52.75	37.5	0.7	0.85	0.6	0.4	5.1	2.2	0.04	0.2	100.3

[a] Li Jiazhi *et al.* (1986b), p. 130.
[b] *Ibid.*

In view of the considerable mineralogical and technical differences that exist between the ordinary and the micaceous Kung-hsien whitewares, it could be argued that the micaceous wares are more deserving of the name 'porcelain' (in the Western sense of combining whiteness, refractoriness and translucency) than regular Kung-hsien whitewares. Nonetheless, among north Chinese porcelains in general, these mica-rich bodies seem peculiar to Kung-hsien, and even there they are only represented at the moment by a couple of sherds.

The great mass of early Thang white porcelains, made mainly in Honan and Hopei provinces, seem closer in their natures to non-micaceous Kung-hsien whitewares, but their lower contents of iron and titanium oxides gave whiter and, occasionally, translucent materials. These slight differences were enough to place many examples within the porcelain, rather than the white stoneware, class.

HSING WARES 邢窯

The world's first true porcelains were actually made in Hopei province, at kilns that made what has come to be known as Hsing ware. Products from the Hsing kilns were copied widely elsewhere in varying degrees of quality. Two kilns that made early, fine white porcellaneous ceramics were those at An-yang and at Nei-chhiu 內丘. The former, making Hsiang-chou ware, reached a peak in the



Fig. 36 Two paper-thin white porcellaneous cups from Nei-chhiu

+6th century.[176] The latter was active from the Northern Wei to Thang periods, 28 separate kilns having been unearthed in the +1980s.[177]

The Hsing kilns themselves were mentioned in tea literature of the +8th century, their bright white porcelain products being especially suited to the drinking of red tea.[178] Hsing ware cups were commended by another later +9th-century text as being one of the premier products of the empire, along with silk clothing, hemp cloth for harnesses, felt for caps and coverings, woven grass belts and inkstones from Kuangtung province: 'The white porcelain cups of Nei-chhiu are used everywhere by rich and poor alike.'[179]

The Hsing kilns were sited on the borders of Lin-chheng 臨城 and Nei-chhiu counties, and although their existence had been lauded in literature, their actual discovery did not come until +1980–2. As is commonplace in China, archaeology proceeded to confirm literary hints.[180] Sui and Thang dynasty kiln sites have been found over a 20-kilometre-long area in this district, with the earliest (third quarter of the +6th century) kilns appearing at Chhen-liu-chuang 陳劉莊. Production of Hsing wares began with coarse celadon wares, and later included a small amount of *san-tshai* ware, although high-fired whitewares were by far the most important products of the district.

Of typical northern *man-thou* 饅頭 type the Sui dynasty Hsing ware kilns were fired in reduction using wood as fuel. At the end of the Sui period Hsing potters invented straight-sided cylindrical saggers, which meant that the finest wares no longer bore spur marks or were marred with kiln debris.[181] Coarser vessels were stacked on top of, or inside, each other using three-pronged supports.[182] The Thang dynasty kilns were also *man-thou* in form (see Part 3), and there is debate about whether they were wood- or coal-burning.[183] Three qualities of ceramic were produced from very fine to coarse. The best wares were fired in saggers of three types. Funnel-shaped, shallow and deep-dish saggers all fired single pieces, and were constructed so that they could interlock and stack.[184] In addition to the Hsing kilns, during the Thang period, white porcellaneous wares were made over a wide area of Hopei, Honan, Shansi and Shensi provinces.[185]

[176] Two levels of An-yang fine ware can be differentiated. The thinnest white cups were placed separately and protected to avoid blemish by firing support, while a slightly thicker, pale celadon version of the same cup had the marks of three-pronged setters inside. Both types of cups appeared in sets of five on a matching tray and surrounded by four jars in burial settings. Excavated wares were observed at the museum at An-yang by the authors in +1997.

[177] Anon. (1987b).

[178] *Chha Ching* ('*Wan*'), p. 9b.

[179] *Kuo Shih Phu, Shu Chung Chi*, p. 5b. Quoted in Feng Hsien-Ming (1987), p. 187.

[180] The Sui dynasty kilns were investigated in +1982, the Thang sites two years earlier, cf. Yang Wen-Shan (1984) and Yang Wen-Shan & Lin Yü-Shan (1981). For a good summary, see Yeh Che-Min (1997).

[181] Bi Naihai & Zhang Zhizhong (1989), pp. 466, 468, fig.II.2,3.

[182] Richards (1986), pp. 61–2.

[183] Ye Zhemin (1996), pp. 63 and 67, discussed the problem in respect of the neighbouring Ting kilns, saying that it was likely that the two centres shared the same fuel, skilled labour force, transport routes and markets.

[184] Richards (1986), pp. 64–6.

[185] *Ibid.*, p. 58.

From the evidence of their compositions, the clays used for Hsing wares were both whiter-firing and more refractory than those used at Kung-hsien. Their whiteness came from unusually low levels of iron and titanium oxides, while their greater refractoriness reflects the paucity of natural mineral fluxes in the local clays, particularly the white micas and feldspars. Hsing wares are the whitest of early northern porcelains, and they can occasionally show some signs of translucency (Table 21).

The firing temperatures for the first two Hsing bodies (described in the report as 'fine white porcelains') are given as 'about 1,360°C'.[186] This was a substantial technical achievement for the time, and rarely exceeded since in Chinese porcelain production. These temperatures are the more impressive for being achieved with kilns that were fired mainly with wood.

If one compares the achievements of Hsing potters in the +7th century with the first European porcelains made at Meissen in Saxony some 1,100 years later, the process both illuminates the skill of the early Chinese makers, and highlights some vital differences between the two materials. One important difference can be seen in the way that the white Kung-hsien wares and Hsing wares seem to have been made mainly from secondary sedimentary kaolins, associated with the coal measures of northern China, while the Saxon porcelains were made largely from primary kaolins, derived from the processing of weathered granite.[187] A further difference appears in the levels of body-fluxes found in the Chinese, compared with the Saxon bodies. In early north Chinese porcelains the levels of calcia, magnesia, potassia and soda are usually minor, while the two early +18th-century Saxon porcelains, by contrast, show high calcia and high potassia contents respectively, reflecting the deliberate addition of alabaster and potash feldspar to the two bodies.

THE NATURE OF HSING WARE RAW MATERIALS

What use (if any) the Hsing ware potters made of added body-fluxes is still difficult to establish, as a number of possibilities could explain the Hsing ware analyses listed in Table 21.

One option might be that the basic raw material for Hsing porcelain was almost a porcelain material in its own right, but it still needed some minor additions of fine quartz, together with some mineral body-fluxes, for its best fired results. Had this approach been used, however, the quantities of extra body-fluxes used would have been modest, barely raising their levels to those that occur naturally in most north Chinese stoneware clays.

Another view could hold that the deposits of clay used for Hsing wares were used much as found, after suitable levigation and sieving, and that the quartz and mineral

[186] Chen Yaocheng *et al.* (1989), p. 227.
[187] Seger (1902a), pp. 48–9.

Table 21 *Analyses of Hsing ware porcelains of the Thang dynasty compared with early Meissen porcelain from Saxony*[a]

Site found	Date	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Total
Lin-chheng	Thang	69.9	25.1	0.6	0.2	0.9	1.6	0.9	0.9	0.01	0.07	100.2
Nei-chhiu	Thang	68.0	27.0	0.6	0.3	0.8	1.5	0.9	0.9	0.02	0.07	100.1
Lin-chheng	Thang	67.6	28.5	0.75	0.4	0.6	0.7	0.75	0.2	-.-	0.05	99.6
Lin-chheng	Thang	60.0	35.1	0.7	0.7	1.0	0.4	1.5	0.5	0.04	0.11	100.1
Böttger porcelain	+1712[b]	61.0	33.0			4.8		0.1	0.2	'rest'	0.9	99.1
Meissen porcelain	+1731[c]	59.0	35.0			0.3		4.0	0.8	'rest'	0.9	99.1

[a] Hsing ware analyses from Chen Yaocheng *et al.* (1989a), p. 224, table 2, and Li Jiazhi *et al.* (1986), p. 130, table 1.
[b] Schulle & Ullrich (1982), p. 45, table 2.
[c] *Ibid.*, p. 45.

fluxes that are obviously present in the fired materials were natural to these clays. This would confine most technological development in the area to improvements in clay preparation, kiln design and management. Improved kiln control in particular would have been necessary to raise the firing temperatures of the wares to the point where the innate qualities of the local clays could be realised.

In addition to these two possibilities, there exists a third, which is that clay-clay, rather than clay-rock, blends may have been used by the Hsing ware potters. In this approach refractory low-silica clays could have been improved by additions of other clays that were richer in quartz and mineral fluxes. This technique for clay design (that is, the mixing of complementary clays) is common practice world-wide, and tends to result in blended ceramic bodies that are technically superior to any of the individual clays that have been mixed to make them.

Of course, for a kiln-complex of this scale, and with such a long manufacturing history,[188] any of these principles could have operated at various sites and at various times, which would change the question as to which approach was the more usual. The main difficulty with resolving this problem concerns the lack of data on local clays. Better information on this subject might show whether the Hsing porcelains could have been made virtually 'as found', or whether some fine-tuning was practised by minor additions of powdered rock and/or complementary clays.

FELDSPATHIC HSING WARES

This issue of how much use early Hsing ware potters made of pulverised rocks was brought into sharp focus by some remarkable discoveries, made at a Sui-Thang dynasty Hsing ware site in the north-west of Nei-chhiu county. Results from these excavations were presented to an international ceramics conference in Shanghai in +1989, where they provided a serious challenge to emerging ideas on the nature of the world's earliest porcelains.[189]

Thirteen samples of Hsing ware levels dating to the Sui-Thang dynasty (early $+7^{th}$ century) were described at Shanghai: three were of the early coarse celadon wares typical of the district; two were of coarse porcelain; and seven were of fine white porcelain. Eleven samples showed compositions already familiar from published work on northern ceramics, but two of the 'fine white porcelains' were of a totally novel type, and showed quite remarkable whiteness, purity and translucency. Both translucent sherds were glazed, and were the remains of small bowls, with their foot-rings still intact. In terms of decoration, one was completely plain, while the other had a sprig of a lion's head applied to its side.[190] The body compositions of these translucent Hsing wares from the Sui-Thang period were established as in Table 22.

[188] Northern Chhi until at least Northern Sung dynasty, late $+6^{th}$ to $+12^{th}$ centuries.
[189] Chen Yaocheng *et al.* (1989a), pp. 221–8.
[190] One of the authors (RK) examined these two sherds at a conference at the Shanghai Museum in +2002.

Table 22 *Analyses of translucent Hsing ware porcelains of the Sui-Thang period*

Site found	Date	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Total
Nei-chhiu	Sui-Thang[a]	65.8	26.8	0.3	0.2	0.4	0.2	5.2	1.0	0.01	0.06	100.0
Nei-chhiu	Sui-Thang[b]	62.9	26.9	0.4	0.2	0.5	0.3	7.3	1.6	-.-	0.01	100.1

[a] Chen Yaocheng *et al.* (1989a), p. 224.
[b] *Ibid.*

Two features stand out clearly in these analyses. The first is the extremely low figures for the earthy colouring oxides of iron and titanium. Titania in particular has a strong yellowing effect on clays when it is present with iron.[191] These sherds showed the lowest figures yet found for titania in early northern ceramic bodies, and they help to account for the unusual whiteness of the sherds. Titania percentages of this order are more typical of primary than secondary kaolins, which may mean that the clays used for these two sherds were refined from weathered rocks, and were true primary materials.

The second feature is the unusually high levels of potassium oxide (K_2O), combined with fairly high levels of sodium oxide (Na_2O) in these clays. Potassium and sodium oxides both operate as powerful body-fluxes at high temperatures, and it was these substantial levels of combined alkalis that supplied the obvious translucency to these porcelains. The authors of the +1989 report explain the analyses thus:[192]

> for the high potash bodies it is very difficult to find a clay nowadays in the North to satisfy the body formula. The only way out is to use potash feldspar, which was seldom used as a major ceramic material by the ancient Chinese potters . . . The presence of a considerable amount of feldspar relics in the bodies . . . provided favourable evidence for the above argument. Calculations were also carried out to find out the possible body formula by using the local ceramic materials. It was found that . . . 60% Zanhuang Baijiayao [Tsan-huang Pai-chia-yao 贊皇白家窯] clay and 40% Neiqiu Shentou [Nei-chhiu Shen-thou 內邱 神頭] potash feldspar could coincide fairly well with that of YN6 [the first analysis in Table 22].

A particular significance of these results lies in the apparent artificiality of their construction, for while mixtures of mica and kaolinite may occur in nature, mixtures of large amounts of feldspar with kaolinite are a far less likely combination. If they were made from processed primary materials, the feldspathic Hsing wares dating to the Sui-Thang period would represent a rather different approach in technology from any northern porcelains of the Sui-Thang-Sung era (+7th to +12th centuries) so far discussed. They would also be much closer in their natures to later Western imitations of Chinese porcelain, and perhaps closest of all to such supertranslucent white porcelains as the English Parian wares of the +19th century.[193]

[191] Lawrence & West (1982), p. 39.
[192] Chen Yaocheng *et al.* (1989a), p. 223.
[193] Parian unglazed porcelain, named after its similarity to fine white marble, was developed by Copeland in about +1845, Honey (1962), p. 235. Hamer & Hamer (1997), p. 238, give a recipe of china clay 33 and Cornish stone (a quartz-feldspar rock) 66 and a firing temperature of 1,200°C.

These excavated sherds represent examples of the earliest truly feldspathic porcelains in the world. They anticipate the major European contribution to porcelain design (the feldspathic hard-pastes of Saxony) by some 1,100 years, and may also show the earliest use of primary kaolin as a major ingredient in a true porcelain body. Their glazes too were unusual in being very rich in feldspar, which would make them the world's first feldspathic glazes. Analyses of many typical Hsing ware glazes show that very low titania kaolins were in general use in glaze recipes at this site, presumably to enhance the whiteness of the underlying porcelain material. Although the low-titania and high-potassia levels in feldspathic Hsing wares place them nearer to southern than to northern porcelains in their natures, their high alumina contents are notably un-southern, and have no close parallels with any south Chinese porcelains yet published.

It seems odd that such a successful technology should have been so briefly used. No further references to feldspathic Hsing wares have appeared in the literature, and the authors themselves note that this technology seems to have died out quite soon in the Thang dynasty: 'That potash feldspar was no longer used is evidenced by the much lower K_2O content in the [Thang] fine white porcelain bodies.'[194]

TING WARE 定窯

It is interesting that the Ting kiln site too has yielded a few very white and very translucent porcelains from the Thang and Northern Sung dynasties, although these have yet to be analysed.[195] Ting wares gradually overtook Hsing ware as China's premier porcelain materials, a process that occurred as the production and reputation of the Hsing kilns began to decline with the end of the Thang dynasty. The Ting production sites were some 100 kilometres further north than the Hsing kiln-complex in Hopei province, but they exploited the same Permo-Carboniferous clay strata, accessible to the east of the Thai-hang mountains, that had already used by the Kung-hsien and Lin-chheng kilns.[196]

By the Five Dynasties period (+10th century) the peak of production at the Hsing kilns had passed, and the main centres were those making Ting and Yao-chou wares 耀州窯. However in the early Sung period, Hsing, Ting and Yao-chou were all still supplying the court with obligatory tribute wares, along with Yüeh.[197] From that point, the Ting kilns reached their zenith during the Northern Sung and Chin periods, and declined during the Yuan. Their provenance was also discovered using literary references, after much debate about location. As late as the +1930s, an American sociologist writing a thesis on Ting-hsien was able to write:[198]

[194] Chen Yaocheng *et al.* (1989a), p. 227.
[195] Ye Zhemin (1996), p. 65. See p. 65, fig. 3, for an early +10th-century example.
[196] Richards (1986), pp. 67–8.
[197] *Thai Phing Huan Yü Chi*, ch. 59, p. 5, ch. 62, p. 4, ch. 96, p. 5. *Sung Shih* ('*Ti Li Chih*'), ch. 85, p. 20, ch. 86, p. 6, ch. 87, p. 4. *Yüan-Feng Chiu Yü Chih*, ch. 2, p. 13, ch. 5, p. 13. *Sung Hui Yao Chi Kao* ('*Shih Huo*'), 41:41.
[198] Gamble (1954), p. 442, from material collected +1926–33.

Ting Hsien is said to have been the site of a flourishing pottery trade up to the time the Chin Tartars forced the Sungs to retreat to Hangchow [Hang-chou]. . . . Although Ting Hsien is said to have been the site of the potteries producing this ware, no trace can now be found of any pottery yards or of any clay beds.

In fact the kilns were not located at Ting-hsien, but at Chien-tzhu-tshun 澗磁村 and Yen-shan-tshun 燕山村 in Chhü-yang county 曲陽縣 in Hopei province. Chhü-yang county was regulated by Ting-chou prefecture during the Sung period, hence the name 'Ting ware' and the confusion over its site location. It was a Japanese scholar, Fujio Koyama, who first investigated the kilns in +1941. The vast quantities of sherds and other material collected on that occasion are preserved at the Idemitsu Museum of Art, the MOA Museum and the Nezu Institute of Fine Arts in Japan, and have been studied in some depth.[199] Further exploratory work was carried out by Chhen Wan-Li 陳萬里 and Feng Hsien-Ming 馮先銘 in the +1950s. Excavation and survey of the vast waster heaps took place in +1961–2, and work has continued to refine knowledge of the products and periodisation of the kilns since then.[200] Material from Chinese excavations is kept in the Cultural Bureau at Chhü-yang and in the Ting-chou City Museum.[201]

Inspection of sherds from the two sites by Japanese scholars revealed that the products of the Chien-tzhu-tshun kilns were homogeneous in materials, being mainly white porcelain, while those of Yen-shan-tshun varied from fine to grey and coarse. The predominant potting method was wheel-throwing, with either carved or moulded designs, the latter first employed in the mid +11th century and employing a single interior mould.[202] Chinese excavation has clarified the picture yet further. Early kilns to the east of Chien-tzhu-tshun dated to the Thang and Five Dynasties period, and yielded celadons, brown-glazed wares and whitewares, some of the latter being white-bodied and refined and some rougher with white slip. Kilns to the north of the village dated to the Northern Sung dynasty and produced whitewares, while other kilns to the east also made Northern Sung white Ting, some marked *shang-shih chü* 尚食局 on the base denoting tribute to the imperial court. Kilns around Yen-shan-tshun made Ting ware through the Northern Sung, Chin and Yuan dynasties, wares becoming coarser as time went on. The range of products was wider than that found at Chien-tzhu-tshun. Items were fired in saggers, and Ye Zhemin [Yeh Che-Min] has characterised firing methods by period: upright firing (*cheng-shao* 正燒) in the early period; upside-down firing (*fu-shao* 覆燒) in the middle period; and stacked firing (*tieh-shao* 疊燒) in the later period. *Fu-shao* firing resulted in somewhat rough, unglazed mouthrims, cleaned free of glaze with a shaped tool before firing to avoid molten glaze adhering to their setters. The *fu-shao* method also caused

[199] Koyama collected 1,167 sherds at Chien-tzhu-tshun, 97 pieces at Yen-shan-tshun and 132 pieces on the way to Chhü-yang county. See Hasebe, Sekiguchi & Nishida (1983), pp. 88–96, 144–9, 160–2, 165–7.
[200] Research work up to +1983 is most usefully summarised by Nishida (1983).
[201] Ye Zhemin (1996), p. 63.
[202] Sekiguchi (1983), pp. 93–5, 161–2.

unglazed rims of vessels to be enhanced after firing, by being bound using copper, silver or gold rings.

Recently another firing technique has been identified, the 'hanging' or 'suspended' method (*kua-shao* 掛燒), whereby vessels, usually open forms, were stacked upright with support rings. The glaze ran towards the base of vessels, which were unglazed beneath the mouthrims. Production processes were standardised, with forming, decorating, glazing and firing carried out by different groups of potters. As at other kilns, clans seem to have appropriated specific areas of manufacture, as is revealed by family names in inscriptions on moulds (for example, *Liu chia mo-tzu* 劉家模子, 'Liu family mould').[203]

Ting kilns were of *man-thou* type and from the +10th century used coal for fuel which gave great heat in the 1,300–1,340°C temperature range, and oxidising firing conditions. This gave Ting ware its characteristic warm ivory tone. In addition to white Ting with its thicker dribbles of transparent glaze known to Chinese connoisseurs as 'tear drops' (*lei-hen* 淚痕), rarer black, brown, green, and brown painted and incised types occur. High-quality ivory, white, purple-brown and black Ting ware was occasionally gilded. As with Thang dynasty Hsing wares, Sung dynasty Ting wares were imitated at a number of other sites.[204]

Ting wares enjoyed high status during the Five Dynasties, Northern Sung and Chin periods, both at court and in wealthy Buddhist monasteries. A government Office for Porcelain Tax Affairs (*Tzhu-yao Shang-shui Wu-shih* 瓷窯商稅務使, often shortened to *Tzhu-yao Wu-shi* 瓷窯務使 or simply *Yao Wu-shih* 窯務使) was established in the area in the Five Dynasties period, an event recorded in a stele dating to +957.[205] Some Ting vessels were inscribed 'official' or 'new official' (*kuan* 官, *hsin-kuan* 新官), a mark that also appears on Yüeh and Yao-chou ware. Ting wares were requisitioned by the palace all through the Northern Sung period.[206] When the Sung court fled south to Hang-chou in +1127, fighting in the north caused temporary interruption to kiln activity. However, activity was soon revived. Overall mining of metal ores had diminished causing shortages of copper, and consequent prohibitions on the use of bronze for ritual vessels. Substitute ceramic ritual vessels were urgently required, and the Ting kilns continued to produce tribute wares.[207] Twelve years after the fall of Northern Sung dynasty,

[203] Ye Zhemin (1996), p. 66; Harrison-Hall (1997), pp. 184–5.

[204] One such was the Ching-hsing kiln 井陘窯 near Cheng-ting 正定 in Hopei province, that was excavated between +1989 and +1996. It yielded a range of material dating from the Sui dynasty to the Yuan that closely resembled ceramics from Chien-tzhu-tshun and Yen-shan-tshun. Indeed, to an untrained eye the two are practically indistinguishable. See Meng Fan-Feng & Tu Thao-Lo (1997), pp. 133–9, pl. 6; Meng Fan-Feng (1997), pp. 140–5. Other sites that manufactured Ting-style wares were Ching-te-chen in Chiangsi; Hsiao-hsien 蕭縣 in Anhui; Peng-hsien 彭縣 in Szechuan 四川; and Phing-ting 平定, Meng-hsien 孟縣, Yang-chheng 陽城, Chieh-hsiu 介休 and Huo-chou 霍州 in Shansi. Hughes-Stanton & Kerr (1980), pp. 102–3; Feng Hsien-Ming *et al.* (1982), pp. 237–9; Vainker (1991), pp. 97–9. Several Tzhu-chou kilns also manufactured substandard versions of Ting ware.

[205] *Chhung Hsiu Chhü-yang Hsien Chih* (1904 edn), ch. 11, p. 135, ch. 12, p. 125. Ts'ai Mei-Fen (1996), pp. 110–11.

[206] For a discussion of Buddhist and court use of Ting ware see Harrison-Hall (1997), pp. 186–7. For a discussion of the significance of the marks see Ts'ai Mei-Fen (1996), p. 114.

[207] *Chin Shih*, ch. 46 ('*Shih Huo*:1'), p. 2; ch. 25 ('*Ti Li Chih*'), p. 10; Kerr (1990), p. 57.

Ting kilns were already in full production making porcelain for the new imperial household.[208]

Since Sung times, Ting wares have been characterised as being first among the 'Five Great Wares' (*wu ta ming-yao* 五大名窯) by collectors, and their fame ensured that they were copied at Ching-te-chen and elsewhere during the Ming and Chhing periods.[209] Many of these pieces, some of the type known as 'earthy Ting' (*thu-Ting* 土定) are extant in museum collections. Most of these imitation wares were produced anonymously in factories, but some have a more illustrious pedigree. The late Ming literati world of the +16th to +17th centuries produced and supported some interesting men who turned their hand to pottery (see pp. 31–3).

As befitted their exalted status, Ting wares attracted attention from Sung dynasty scholars such as Lu Yu 陸游 , Yeh Chih 葉置 and Chou Mi 周密 , but it was the early Ming author Tshao Chao 曹昭 who described their quality and value as collectables in some detail:[210]

> Among ancient Ting ware pieces with fine body and white, lustrous glaze are valuable, while those that are coarser and yellowish are less so. Genuine items have 'tear drop' markings on the exterior. The best have incised patterns, the second best are plain, while the third best have brocade patterns [probably moulded designs]. The best Ting wares were made in the Hsüan-Ho and Cheng-Ho reign periods . . . There are also purple and inky Ting wares, the latter as black as lacquer, though the bodies of both are also white. Like white Ting they were made at Ting-chou but are more expensive . . . white Ting, if it is damaged, cracked or dull, is inexpensive.

Tshao also said that in his time Ting ware was already more expensive than fine imperial wares from Ching-te-chen.[211]

COMPOSITION OF TING WARES

The beautiful cream-coloured porcelain made by the Ting kilns was, in its heyday of the Northern Sung to Chin dynasties, fired with coal in a generally oxidising atmosphere. Kiln temperatures for Northern Sung dynasty Ting wares have been estimated at *c.* 1,320°C ± 20°C,[212] and the material can occasionally show signs of an orange-tinged translucency. However, many grades of Ting ware were made, many of which should be placed into the stoneware class, as they appear totally opaque and cream in colour (Table 23).[213]

[208] *Ta Chin Chi Li*, ch. 9, p. 9, mentions 1,000 Ting ware items as being part of an official list of goods ordered for a princess of the royal household.

[209] For example, in the spring of the 7th year of Yung-Cheng (+1729), an order (retrieved from the Chhing dynasty palace archives) was addressed to Nien Hsi-Yao 年希堯 to produce imitation white Ting vessels, see Fu Chen-Lun & Chhen Li (1982), pp. 21–2, 55–6.

[210] *Ko Ku Yao Lun*, ch. 3, pp. 39a–b. David (1971), pp. 141, 306.

[211] *Ko Ku Yao Lun*, ch. 3, p. 40a. David (1971), pp. 143, 305.

[212] Li Guozhen & Guo Yanyi (1986), p. 138.

[213] See Chang Chin *et al.* (1983), pp. 14–35, for a full account of the technological characteristics of Ting ware.

Table 23 *Analyses of Ting ware bodies*[a]

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	Total
Ting ware body 1 Thang	59.8	34.5	0.4	0.7	1.1	0.9	1.25	0.7	0.03	99.4
Ting ware body 2 Five Dynasties	61.2	32.9	0.6	0.6	3.4	0.9	1.25	0.1	0.02	101.0
Ting ware body 3 Northern Sung	62.0	31.0	0.5	0.9	2.2	1.1	1.0	0.75	0.04	99.5
Ting ware body 4 Chin	59.2	32.7	0.75	0.7	0.8	1.1	1.7	0.3	0.01	97.3
Böttger porcelain +1715[b]	61.0	33.0	-.-	-.-	4.8	-.-	0.1	0.2	'rest' 0.9	99.1
Vienna porcelain late +18th century[c]	61.5	31.6	-.-	0.8	1.8	1.4	2.2	-.-	-.-	99.3

[a] All Ting ware analyses: Li Guozhen & Guo Yanyi (1986).
[b] Schulle & Ullrich (1982), p. 45, table 4.
[c] Brongniart (1844), vol. 2, p. 386.

Table 24 *Analysis of Ling-shan purple clay*[a]

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Total
Ling-shan purple ball clay: fired	55.6	40.0	2.0	0.7	2.0	1.0	0.2	0.5	-.-	-.-	102

[a] From Li Guozhen & Guo Yanyi (1986), p. 138, table 3. (The raw clay analysis in this table has been calculated to its fired state.)

A significant technical feature of Ting ware bodies, and one that has been much discussed, is the occasional above-average levels of calcia and magnesia that appear in its analyses, particularly during the porcelain's prime period of production in the Northern Sung and early Chin dynasties. The levels of alkaline earths found in some Ting wares do not approach those used in Böttger's porcelain, but are very similar to Vienna porcelain, which was made from +1718 onwards, originally with Saxon raw materials and using Meissen expertise.[214] It is one of the paradoxes of world ceramic history that the first European hard-pastes were made to copy contemporary south Chinese porcelains (the major Chinese type of the time), but instead produced hard-paste recipes wares that were technologically far closer to the long-abandoned clay-rich porcelains of northern China. In both Meissen and Vienna porcelain the calcia and magnesia contents represent deliberate additions, which raises the question of whether these alkaline earth figures in Ting wares were also the results of deliberate additions, or were merely typical of the local Hopei clays.

Some weight for the latter view may come from analytical work on clays in the Ling-shan 靈山 district, near to the Ting kilns, in particular from a high-firing clay that showed CaO-MgO figures comparable with many Ting ware examples of the Sung and Chin dynasties (Table 24).

The 'purple' clay is unusual geologically as even slightly above-average levels of calcia and magnesia in clays tend to be found together with raised levels of iron

[214] Kingery (1986), p. 170.

Table 25 *Analyses of Yao-chou whiteware bodies*[a]

Dynasty	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	(rest)	Total
Thang	63.65	29.8	1.1	1.0	0.7	0.5	1.5	0.6	(0.6)	98.25
Thang	67.4	27.6	0.6	1.0	0.4	0.5	1.6	0.4	(0.9)	98.9
Northern Sung	58.6	34.7	0.6	0.1	2.6	0.8	1.2	0.7	(0.7)	98

[a] Zhang Zizheng *et al.* (1985), pp. 22–4 (data from poster paper).

Table 26 *Analyses of Huo-chou ware whiteware bodies*[a]

Dynasty	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Total
Yuan	57.4	39.4	0.5	0.7	0.4	0.2	0.9	0.5	0.01	0.04	100.1
Yuan	57.9	38.6	0.9	-.-	0.4	0.3	1.0	0.5	0.004	0.05	99.7

[a] Kuo Yen-I *et al.* (1999), p. 216, table 2.

oxides, a feature that this clay does not show. The association of calcia and magnesia with iron in most clay analyses tends to reflect their origins from weathered intermediate or basic rocks, which are rich in all these elements. The fusible earthenware clays used for early Iraqi tin glazed earthenwares (made to copy imported north Chinese porcelains) are good illustrations of this principle, as indeed are most clays used for tin-glazed earthenware throughout its long history in the Middle East and in Europe.[215]

Returning to the purple ball clay, its high titania content would have made it unsuitable for porcelain-making, but its existence does suggest that low iron refractory clays, relatively rich in calcia and magnesia, and low in iron, could have existed near to the Ting ware kiln sites. Such clays could have been exploited by the local potters.

The alternative of course is that the Ting ware potters simply added dolomite, quartz, and even minor amounts of feldspar, to ordinary refractory clays, in order to aid vitrification and to reduce the firing temperatures of their clays. This is a view held by Guo Yanyi [Kuo Yen-I 郭演儀] of the Shanghai Institute of Ceramics, who writes:[216]

> In order to supply the required amount of oxides in the body it was necessary to take as the main ingredient a local clay, such as the Ling-shan refractory clay, which was the most suitable, and add 10–20% feldspar and quartz, as well as a small amount of dolomite and calcite.

[215] Tite *et al.* (1998), p. 255; Zhang Fukang (1992), table 1, p. 384.
[216] Guo Yanyi (1987), p. 15.

Other Northern Porcelain Sites

Although clays from the eastern foothills of the Thai-hang mountains supplied most of north China's porcelain production in the Thang to Yuan period (+7th to +14th centuries), white porcelains were also made to the west of these mountains, in Shensi and Shansi provinces. The Yao-chou whitewares of Shensi province were interesting in being even more refractory than Hsing wares, with firing temperatures approaching 1,370°C (blue-white heat) being necessary to mature the material.[217] These temperatures became easier to achieve when coal firing was perfected at Yao-chou in the Northern Sung dynasty, and the local whiteware material was somewhat immature before this period. The use of such high temperatures, with their consequent high costs in firing, and associated wear on kilns and setting refractories, suggests that there was little awareness at Yao-chou of the principles of adding body-fluxes to porcelain, which in turn suggests the fairly direct use of local porcelain clays (Table 25).

Perhaps the most refractory of all northern whitewares are those used for Yuan dynasty whitewares at the Huo-chou ware 霍州窯 kilns in Shansi province.[218] With alumina contents as high as 39%, and correspondingly low flux contents, the Huo-chou wares must have needed temperatures above 1,350°C to mature them. These compositions also imply the direct use of local low-iron refractory clays without any flux- or silica-rich additions (Table 26).

[217] Zhang Zizheng *et al.* (1985), pp. 23–4. (The full text is unpublished; the data are taken from a poster-paper.)
[218] Huo-chou ware sherds are illustrated in Hughes-Stanton & Kerr (1980), pp. 102–3, 162.

STONEWARE IN NORTH CHINA IN THE POST +10TH CENTURY

NORTHERN STONEWARE

The prime interest in northern porcelain was the body-material, and rather neutral transparent glazes were devised to show these clays to their best advantage. With the finest northern stonewares, by contrast (particularly those of the Northern Sung dynasty), the qualities of the high-fired glazes were the most notable feature of the wares, and the characters of their clays somewhat secondary.

Nonetheless, and despite these later successes, northern stoneware glazes took some centuries to mature from their rather primitive beginnings in the +6th century, when pale kaolinitic clays were enhanced with simple greenish lime glazes or their amber oxidised equivalents. Such +6th-century glazes tended to be glassy, fluid and finely crazed, but could occasionally exhibit a dull mattness from the effects of slow cooling or from under-firing, or strong opalescence from liquid-liquid phase separation (see pp. 534–5).

With the rise of whitewares at many northern sites during the Thang dynasty, celadon glazes declined in popularity, giving rise to the maxim 'whitewares in the north and greenwares in the south' as a catch-all description for Thang high-fired ceramics. This period also saw a substantial rise in northern black-glazed stoneware, which often used glazes made from the local loess deposits. Thang dynasty stonewares were usually fired to somewhat lower temperatures than contemporary northern porcelains, often within the 1,250–1,300°C range, and in predominantly oxidising atmospheres.

Typical glazed stonewares from north China in the Thang dynasty therefore tended to be oxidised (black, off-white or yellow), with their glazes often stopping some way short of their feet to reveal the pale stoneware clays beneath. This partial glazing was a survival from a +6th-century practice when unstable lime glazes of the time ran easily in firing, so a good gap was left to minimise sticking. Partial glazing also occurs on many *san-tshai* 三彩 wares, in this case to prevent the rather fluid lead glazes from over-running their bases. Porcelains of the Thang dynasty, by contrast, were often glazed overall (apart from their foot-rings), a process that was assisted by the high viscosities of their clay-rich glazes.

YAO-CHOU 耀州

With the end of the Thang dynasty early in the +10th century, reduction-fired celadons enjoyed a revival in northern China. This was true of the Yao-chou kilns, where first bluish, and then fresh-green and olive-green, lime-alkali glazes were

developed. The county in Shensi province where the kilns were sited (Thung-chhuan Hsien 銅川縣) was once known as Yao-chou, and its ceramic productions later celebrated in China as *Yao-chou yao* 耀州窯.

Yao-chou celadon glazes were higher-firing and more stable than their south Chinese equivalents and could therefore be applied to greater thicknesses. Such glazes proved ideal to enhance carving, combing and, later, moulding in the clay surface. The Yao-chou stoneware clays contained slightly more iron oxide than earlier northern stonewares, and tended to reoxidise to warm iron tones at high temperatures and during the early stages of cooling. The local gazetteer indicated that clay sources were local, lime coming from Thung-kuan 同官 and fine clay from Chhen-lu-chen 陳爐鎮.[219] This fine, off-white material called '*kan-ni* 坩泥' or '*kan-thu* 坩土' was a porcelain clay, and the provincial gazetteer described its use:[220]

Kan-ni from Chhen-lu-tshun is white and fine and can be used for making porcelain (*tzhu-chhi* 瓷器); Ming-yüeh mountain 明月山 produced white clay like silver, and also *kan-ni*, that was used for making official porcelains.

Connections between whitewares and greenwares of north China can be established not only through material properties, but also through patterns of manufacture and consumption. The most important area making mainly greenwares was Yao-chou, corresponding to today's Thung-chhuan county. Within Yao-chou, two important kiln sites were Huang-pao 黃堡 and Chhen-lu 陳爐. The presence of coal deposits in the same areas as ceramic clay encouraged the transition from wood to coal firing, probably in the later +10th century. In the Northern Sung dynasty there was considerable economic expansion, aided by government sponsorship of mining and other industries. Improvements in coal mining in turn caused rapid growth in the ceramic industry. The use of coal, with its short flame length, led to adaptations in design of the distinctive *man-thou* kiln (see pp. 316–22), that had first been developed to burn wood.

The success of Yao-chou led to its later imitation at a number of kilns in Honan province, such as Lin-ju 臨汝, I-yang 宜陽, Pao-feng 寶豐, Hsin-an 新安, Nei-hsiang 內鄉 and Yü-hsien 禹縣.[221] Material excavated from the Yen-ho-tian 嚴和店 at Lin-ju is held at the Sackler Museum in Peking. Although Lin-ju ware copied Yao-chou ware faithfully, some differences may be discerned through optical examination, which suggests that Lin-ju ware tended to be more highly fluxed and faster-fired. Such was the fame of Yao-chou ware that it was even copied in Kuangsi province, where the distinctive celadon green was either achieved in the usual manner using iron oxides, or in a unique fashion utilising copper compounds.[222]

[219] *Shensi Thung Chih*, ch. 35:3, p. 12.
[220] *Ibid.*, ch. 43, p. 116.
[221] Feng Hsien-Ming *et al.* (1982), pp. 251–2.
[222] These important finds were reported in English by Scott & Kerr (1993) and Scott (1995).

Historical Monuments Documenting Stoneware Manufacture

The important part played by ceramics in Chinese material culture is attested by local monuments erected to honour or seek the help of a divine patron of potters. This deity was worshipped at many kilns, and bore a variety of names (see also pp. 206 and 243–4). Several extant monuments in the northern stoneware area record information about a Patron Deity of Kilns. A large number of stone stelae have been preserved that also tell us a lot about the pottery industry.

An early example dates to +1008 and was found among over ten other stelae, in a temple dedicated to the God of Kilns in Hung-shan-chen 洪山鎮 in Shansi province.[223] The inscription bears the names of two officials of the local ceramics tax bureau, an office that was also established 75 years later at Ching-te-chen.[224] It further describes the buoyant state of ceramic manufacture and trade, and the fine quality and high reputation of local products. Interestingly, the stele uses the word *thao* 陶 for pottery, describes items using the adjectives *tshui* 翠 (jade green) and *hsi* 稀 (rare). It was dedicated to the God of Kilns, *Yüan Shen* 源神, a title for the deity that was changed to *Te-ying Hou* 德應侯 ("Marquis of Te-ying"), later in the +11th century (see note 225 below).

Two other Sung dynasty and three Chhing dynasty memorial tablets were found in temples dedicated to the God of Kilns.[225] A stele dated +1084 was set up at Huang-pao.[226] It is informative and succinct about the manufacture of Yao-chou ceramics, describing it thus:

> as clever as gold working, as fine as jade carving [is] the mixing of clay for shaping and the wheel-throwing of consistent, round or square, large or small [vessels]. [They are] placed in the kiln and fired vigorously, with green smoke dispersing. After several days of toil, they are ready. Their clear ring tells of their strength and their subtlety lies in their colour…

It continues with an imaginative description of combustion: 'Looking in to the kiln, with its strong fire, one often sees insects, which must be gods in disguise, moving in shimmering pure water.'

A potter called Po-Lin 柏林, whose surname had been forgotten and who lived in the Chin dynasty (+4th century) in neighbouring Shansi province, was celebrated on the stele at Huang-pao. His achievements were recorded on the tablet that had been hidden in the beams of a temple. The importance of Huang-pao as a

[223] Wu Lien-Chheng (1958), pp. 36–7; Feng Hsien-Ming *et al.* (1982), p. 250.

[224] A network of government offices controlling ceramic trading and taxation was established across China. Thus in the eighth month of +1083 a trading bureau administrative office for the porcelain kilns was opened at Jao-chou 饒州, while in +1084 an additional bureau was established at Lan-chou 蘭州 for overland trade across Central Asia. *Sung Shih* ("*Shih I Wu*"), *HH* edition vol. 1, p. 462.

[225] The Marquis of Te-ying 德應侯, was an official title bestowed on one who was also known as the God of Mountain and Earth. The inscription on the stele at Thung-chhuan indicates that in the reign of Hsi-Ning (+1086–77) the Spirit of the Kilns (*yao-shen* 窯神) was ennobled as Marquis of Te-ying.

[226] Chhen Wan-Li (1972, 1976), p. 35; Feng Hsien-Ming *et al.* (1982), p. 252; Hsüeh Tung-Hsing (1992), pp. 14–15, who reproduces the inscription; Mino Yutaka (1980) who reproduces a rubbing of the stele.

kiln centre grew with time, until in the Sung dynasty the local gazetteer described numerous ceramic factories, and the very temple where the stele tablet was found.[227]

Yao-chou clearly prided itself on its pottery industry, for three more commemorative tablets were situated there, dated +1727, +1817 and +1882.[228] All of them recall the past glory of the town at its peak of activity during the Sung and Chin dynasties. Archaeological work has shown that wares of lesser quality were made during the Yuan dynasty, while an excavated sagger with the reign mark of Hung-Chih (+1488–1505) suggests that some sort of activity continued into the Ming.[229]

A Sung dynasty tablet of +1105 was found in the small village of Tang-yang-yü 當陽峪 in Hsiu-wu county 修武縣, in neighbouring Honan province. Although it is damaged and broken, a dedication was made to the Marquis of Te-ying, whose given name was Po-Lin. The temple was founded in +1100 and the stele erected in +1105. Also included is information that the concept of dedicating a temple to ceramic production originated at Yao-chou, and that over 100 local families were working in pottery production, supporting over 10,000 people. On the back of the stele is a ballad introduction by Chheng Kung 程公 from Chiang-nan 江南. The date of this inscription is unclear; it could be contemporary, or added at a later date. It mentions fine pottery craftsmanship at Tang-yang-yü, with a flattering comparison to wares from Chheng's home town of Pho 鄱 in the south, i.e. Ching-te-chen.[230]

Other Important Northern Stonewares

In the Northern Sung dynasty north Chinese celadon glazes evolved into such major new ceramic types as Chün ware and Ju ware, particularly at kilns in Honan province. These thick bluish and bluish-green glazes were often used on simple but highly expressive forms to create a refined monochrome style. At the same time, lower grades of stoneware, dipped in white kaolinitic slips, were decorated first by carving and then, later, by lively painting in black slip, beneath slightly dull clear glazes. These were the Tzhu-chou wares of north China, produced in enormous quantities in many northern provinces.

Ju Ware 汝窯

Ju ware was one of the collectors' 'Five Great Wares' 五大窯 and was referred to reverentially in literature almost from the moment that it was first made. Ju vessels were carefully preserved in palace storerooms at least as early as the Ming

[227] *Yao-chou Chih*, ch. 2 (*Ti Li, Thung Kuan Kü Jï*), p. 76.
[228] Feng Hsien-Ming *et al.* (1982), pp. 251–2.
[229] *Ibid.*
[230] Chhen Wan-Li (1954), pp. 44–5; Mino Yutaka (1980), p. 12.

dynasty,[231] and until recently less than 40 items from the palace collection (preserved mainly in China, Taipei and London) were thought to represent the sole corpus of extant Ju ware. This situation changed in +1987, when sherds resembling Ju ware were discovered by a chance sequence of events, and land at the edge of the village of Chhing-liang-ssu 清涼寺 near Pao-feng 寶豐 in Honan province was excavated.[232] No kilns and workshops were found, but enough sherds of Ju ware, saggers and kiln furniture remained to establish production. New excavations in the centre of the village in +2000 confirmed this simple, remote spot as being a centre of production for imperial Ju ware in the late Northern Sung dynasty. More than fifteen *man-thou* kilns, two workshops areas, and mounds of kiln debris and sherds operated intensive manufacturing for a short twenty-year period between *c.* +1086 and +1106.[233]

The majority of Ju was fully glazed and fired upright in saggers, on either three- or five-spur setters that left trademark, small, sesame-shaped spur marks on the base. Ju ware was produced for a very short time and its archaeological context demonstrated that it was only one of many wares made at the same site. Inferior-quality Ju and Chün type wares were made there, as well as blackwares and decorated Tzhu-chou type ceramics.[234] It is clear that Ju ware, like tribute Yüeh ware, was formed and fired as special commissions for the court at commercial kilns, rather than at dedicated official workshops. Another literary connection with Yüeh ware was established by Hsü Ching 徐兢 (+1123) when writing about good-quality incense burners, for he opined that Yüeh 'secret colour' wares were the best old type, while new wares from Ju-chou were the best modern type.[235]

Ju ware was obviously highly esteemed by the Northern Sung dynasty court, its value in relation to other rare and costly items established by a preserved imperial gift list. The gift was made by an aspiring official called Chang Chün 張俊, on the occasion of the Emperor Kao Tsung's 高宗 visit to the Chang mansion in +1151. The list included 42 jade vessels, gold, pearls, kingfisher feathers, glass, agate, ancient bronzes, precious textiles, hides, calligraphy, paintings, and sixteen items of Ju ware. The latter comprised two wine flasks, one basin, one incense burner, one incense box, one incense sphere, two incense stands, four cups, two spittoons, and a large and a small cylindrical censer.[236] Many of these large forms were previously unknown in extant Ju ware, the limited number of pieces preserved in museums tending to be small in scale. Today, thanks to continued excavation, many of the shapes mentioned in literature have been found (see Fig. 37).

[231] *Hsüan-Te Ting I Phu*, p. 1a, which says palace storerooms preserved Ju ware along with valued Chhai, Kuan, Ko, Chün and Ting wares. This book was included in *Ssu Khu Chhüan Shu* with a preface dated +1428; for a discussions of its authenticity and dating see Kerr (1990), p. 105, note 12.

[232] Wang Qingzheng (1991a), p. 27; Wang Qingzheng (1991b), p. 85.

[233] Chhen Hung-Yen *et al.* (2001) and Anon. (2001c), *passim*, and especially p. 28.

[234] See Wang Qingzheng (1991a) and (1991b); Vainker (1991), pp. 99–101.

[235] *Hsüan-Ho Feng Shih Kao-li Thu Ching*, ch. 32 ('*Chhi Min San*'), p. 2b. For a history of the text recensions see David (1938), pp. 20–2.

[236] *Wu-lin Chiu Shih*, ch. 9, p. 13b. For history of text recensions see David (1938), pp. 22–5.



Fig. 37 Excavated fragment of a lotus stand, probably part of a large incense burner. No whole Ju ware vessels of this type survive

CHÜN WARE 鈞窯

The discovery of Chün type ware at the Ju kiln at Chhing-liang-ssu was just one of many occurrences of Chün ware in Honan province. The majority of Chün wares came from at least ten manufactories in Lin-ju 臨汝 and Yü-hsien 禹縣 in central Honan. The kilns made other pots as well as Chün ware, primarily celadons, but also decorated wares. Chün wares were made in a wide range of shapes and in general were popular wares for general consumption. Their greatest beauty lay in the glaze, that ranged from milky blue to brilliant purple, and was often enlivened by splashes of high-fired copper-red pigment.

Sturdy Chün wares were made in a variety of qualities, the best of which was fine-bodied and fired on spurs. Shapes tended to be large and utilitarian, such as bulb pots and planters, but the beauty of that refined type was exemplified by subtle and beautiful glazes. By the late Ming dynasty it had won commendation and was deemed to be one of the 'Five Great Wares'. Scholars such as Kao Lien 高廉 and Chang Ying-Wen 張應文 elaborated graphically descriptive hierarchies of colours and types, from the best red and blue-green wares, down to those whose colours had merged in the kiln to a muddy brownish-pink colour 'like pig's liver' (see also p. 570).[237]

[237] *Tsun Sheng Pa Chien*, ch. 2, pp. 24a–28b. *Chhing Pi Tshang*, ch. 4, p. 6b.

TZHU-CHOU WARE 磁州窯

Tzhu-chou ware was a popular ware that took its name from the type-site in Tzhu county 磁縣 in Hopei province. However, it was manufactured at a great number of sites in Hopei, Honan, Shensi, Shansi and Shantung provinces during the Sung, Chin, Yuan and Ming periods. Country wares in the Tzhu-chou tradition continued to be made for local use after that time, down to the +20th century. The kilns were untrammelled by a need to conform to imperial orders, and their pots were both practical and lively. During the Sung and Chin dynasties, innovative designs and technologies developed. Northern blackwares saw major advances in the +10th and +11th centuries and were now decorated variously by direct carving through the glaze, decoration on the glaze with splashes of rust-coloured glaze of equivalent maturing temperature, or by more detailed iron-rich painting that created rusty semi-figurative patterns against the black-glaze ground.[238] Cut-glaze techniques called *sgraffito* by Western writers were innovative and intricate. Some involved designs being cut through the glaze to reveal contrasting body-material below, and others the carving away of a top glaze to reveal a whitish slip beneath.[239] Tzhu-chou potters also pioneered glaze inlay decoration in the +10th century, whereby glazes were cut to produce a pattern that was subsequently filled with contrasting slip or glaze material. Inlay techniques were later refined in Korea during the Koryŏ period, and in Japan during the Edo period. In addition to white and black wares, there were monochrome green and yellow overglazes, and painted wares.

Some of the painting was done in underglaze iron, but starting *c.*+1200 painted overglaze enamel decoration was adopted. This technology was subsequently employed on porcelains at Ching-te-chen in the +14th century (see Part 6 of this volume).[240]

The earliest ceramics related to Tzhu-chou have been found in Northern Dynasties tombs, though no kilns from that time have yet been discovered.[241] However, true Tzhu-chou wares arose in the late Five Dynasties to early Northern Sung period, *c.*+925 onwards. In the Sung and Yuan periods there were two main centres in Hopei province making Tzhu-chou ceramics, each encompassing a cluster of separate kiln sites: the Pheng-chheng 彭城 area near Han-tan 邯鄲; and the Kuan-thai 觀台 area in Tzhu county. Both were well-sited for raw materials that were dug from the banks of the watercourses along which ceramics were transported from the kilns.[242] In addition to the main centres of production in Hopei, a great number of

[238] See Mowry (1996), pp 31–6, for a survey of Tzhu-chou style blackwares.

[239] Typical excavated examples of this technique are illustrated in Hughes-Stanton & Kerr (1980), pp. 154, 157, 161, 163–4.

[240] Cf. Scott *et al.* (1995); Kerr *et al.* (1995); Vandiver *et al.* (1997).

[241] Wares of Eastern Wei and Northern Chhi dynasty date are displayed at the museum in Han-tan 邯鄲 in Hopei province, epicentre of Tzhu-chou production.

[242] See Anon. (1997d); Chhin Ta-Shu (1997), p. 81. It was recorded that in the Ming dynasty Pao-shan at An-yang 安陽寶山 and Pai-thu-shan at Tzhu-chou 磁州白土山 supplied white stone and white clay for the making of Pheng-chheng ware, cf. *Ying-te Fu Chih*, ch. 1, p. 12, ch. 2, p. 30. It is likely that these two sources of raw materials were active much earlier.



Fig. 38 Pillow with slip-inlaid decoration, early northern Sung dynasty, +10th century

kilns in Honan, Shensi, Shansi, Shantung and even as far north as Ninghsia made variants of 'Tzhu-chou type ware'.[243]

One of the type sites, Kuan-thai, is selected here for brief review. Kuan-thai ceramics are very prevalent among collections; for example, it has been estimated that 40% of Tzhu-chou pots in the Palace Museum collection in Peking came from Kuan-thai. The site has been subjected to detailed archaeological examination in recent years.[244] The archaeologists outlined four major phases of development there, that can be used as a paradigm for events elsewhere:

Phase 1 (c.+925–1048)

The kilns first developed a relatively small output and range of daily-use items, mainly white- or black-glazed but with some high-fired iron-brown and low-fired green decoration. A limited range of decorative techniques were employed including colour-splashing, painting, incising, stamping and the use of a pearl-stamped or painted ground. Most wares were fired unprotected in stacks using thick,

[243] For types from various provinces, see Hughes-Stanton & Kerr (1980), pp. 80–4, 86–90, 100–1, 104–8, 154–8, 161, 163–4.

[244] The excavation is reported in Chhin Ta-Shu (1997), pp. 81–92. Facts reported here are derived from that article, and from Anon. (1997d).

three-pronged supports and some rim-to-rim firing, though some of the finer wares used saggers.

Phase 2 (c.+1068–1148)

After a twenty-year gap for which no finds were made, a period of development followed from the mid Northern Sung to early Chin periods. Larger forms appeared such as jars, vases and pillows while decoration expanded to include some glazing with low-fired green and yellow. All items were now fired in saggers using three- or five-pronged supports. From *c.*+1100 onwards stacked firing inside saggers started, plus firing on the mouthrim (*fu-shao* 覆燒) and the use of funnel-shaped saggers for single larger vessels. Glaze quality improved because of the use of saggers.

Phase 3 (c.+1148–1219)

In this, the mid to late Chin dynasty, the kilns flourished. A multiplicity of forms and decorations appeared and markets expanded to include ornamental, temple and architectural items, in addition to household wares. Ceramics became thinner-bodied and although fewer blackwares were made the production of yellow and green wares increased. For the first time, red, green and yellow painted designs on a white slip ground occurred. Firing methods included stacked firing in saggers using 3-pronged supports, firing on the mouthrim and single-item sagger firing. Fewer wares were stacked mouth-to-mouth and indeed at this time wares were stacked in saggers both upside-down and the right-way up.

Phase 4 (c.+1219–1350)

The arrival of Mongol troops in Tzhu-chou heralded a period of decline. The kilns were reduced to producing household wares once more, including large forms such as heavy dishes, bottles and jars. Black and white continued to be the major decoration, with some yellow and green prior to *c.*+1300. Turquoise-glazed wares appeared for the first time, as did the production of Chün glazes. In the +13th century whitewares were dominant with hardly any blackwares, whereas in the +14th century there was a sudden renewal of interest in monochrome black glazes, with many of superlative quality being manufactured in single saggers.

Kuan-thai, along with other kilns in the region, stopped production in the late Yuan and at the beginning of the Ming dynasty. This was caused by the exhaustion of raw materials and changes in the course of the Chang river 漳河, and by escalating production at other local kilns.

During the Ming period and later, Tzhu-chou-type wares continued to be made at northern kilns. For a period in the Ming dynasty, the kilns even supplied domestic



Fig. 39 Tzhu-chou vase with incised design and red, yellow and green enamels over white slip ground, +12th to early +13th centuries



Fig. 40 Deep stratigraphy at the Kuan-thai kiln site, +1997

vessels to the imperial court. Shansi province dispatched clay cooking pots, as many as 150,000 at a time.[245] *Ta Ming Hui Tien* (The Collected Statutes of the Ming Dynasty, +1503–1642) records that in the Hsüan-Te reign period the Court of Imperial Entertainments (*Kuang-lu* Ssu 光祿寺) ordered 51,850 wine crocks, jugs and bottles from Tzhu-chou and Chün-chou.[246] In +1459 large cisterns of superior quality were made at tile-firing kilns (*liu-li yao* 琉璃窯), and it was specified that these special orders used clay from Chen-ting Fu 真定府 in Hopei province, and fine white slip and glaze materials from Khai-feng 開封 in Honan province. In +1522 a consignment of cisterns with alkali-glazed exteriors (i.e. with turquoise, aubergine and purple glazes) was supplied for imperial domestic use.[247] As late as +1637 *Thien Kung Khai Wu* noted that very large 'dragon and phoenix' jars manufactured at Chhü-yang for use at court were made with very thick walls so that designs could be carved in high relief.[248] But the northern Tzhu-chou kilns lost ground to Ching-te-chen, and by the Chhing dynasty had reverted to the production of household items for local use. In the same period some southern kilns, for example, those in Anhui province, had also been supplying coarse wine vessels to the palace. The need for 'official jars' (*kuan-phing* 官瓶) was enormous, for the Court of Imperial Entertainments used them for innumerable official banquets and rituals. Thus kilns at Hsüan-chheng 宣城 in Anhui supplied jars annually to no fixed quota, at first with wine in them but later dispatched alongside the wine, which was made separately. Orders were large, a typical sample being 120,000 items.[249]

Compositions of Northern Clays

Taken together, the Northern Sung stonewares of north China display a richness, complexity and artistic quality that soon eclipsed the long-established ash-glazed stonewares of the south. Northern kilns were also surprisingly versatile in their productions. Both the Kuan-thai and Pao-feng kilns made Chün wares, blackwares and celadon wares, together with endless variants of the northern Tzhu-chou style, and all within the same kiln-complexes.[250]

Overall, the Northern Sung and Chin dynasties represented a golden age for north Chinese stonewares and porcelains, and this era still stands as one of the greatest creative episodes in the history of world ceramics. However, production of the very finest wares suffered from the Chin Tartar invasion of +1127, and this setback was compounded by the Mongol reinvasion of +1234. These were shocks from

[245] *Shansi Thung Chih* (1734 edn), ch. 47, p. 16.

[246] *Ta Ming Hui Tien*, ch. 194, p. 1b/2631. The Court of Imperial Entertainments was a division of the palace in charge of catering for the imperial household, court officials and imperial banquets honouring foreign envoys and other dignitaries, see Hucker (1985), p. 288.

[247] *Ta Ming Hui Tien*, ch. 194, p. 1a/2631.

[248] *Thien Kung Khai Wu*, ch. 7, p. 4a.

[249] *Ning-kuo Fu Chih* (1536 edn), ch. 6, p. 12 (1815 edn), ch. 18, p. 10.

[250] For examples of Pao-feng wares, see Hughes-Stanton & Kerr (1980), pp. 89–90; for a summary of the major ceramic types from the Kuan-thai kilns, see Anon. (1997d), pp. 587–99.

which the fine ceramics of northern China were unable to recover. The only substantial ceramic innovations that occurred in north China after this time were the dramatic northern *fa-hua* 琺華 wares that used low-temperature turquoise-blue, inky black, aubergine and purple glazes over a white-slip ground, all applied to underfired stoneware bodies.[251]

Splendid though northern stonewares of the +11th to +13th centuries were in style, ornament and glaze quality, the clays used to make them hold few surprises. Compositionally, they can be regarded as close relations to northern whitewares, but with higher levels of colouring oxides, particularly those of iron and titanium. As with porcelains, high alumina and low potassia levels can be traced in stoneware clay compositions across north China, and this suggests that most northern stonewares were derived from similar clay systems to the porcelains. Indeed a number of whiteware kilns (such as the Hsing and Ting kilns) produced stonewares, while many stoneware kilns (such as Yao-chou and Kuan-thai) also made whitewares. The white slips used for Tzhu-chou production were similar to low-grade porcelain clays, and were also used for this purpose at some Tzhu-chou sites.[252] Analyses of the major types of northern whitewares and stonewares are listed in Table 27, and the minor differences that exist between them also help to explain some of the wares' more obvious visual characteristics.

In greater detail, northern stoneware can be considered from the standpoint of their major producing-kilns, as the small differences that exist between these bodies help explain some of the wares' more obvious visual characteristics.

The most notable technical feature of the Ju ware clay was its high refractoriness, due mainly to its low levels of alkalis (potassia+soda) (Table 28). At typical firing temperatures for Ju wares (*c.* 1,220–1,240°C) these clays produced rather immature stonewares that reoxidised easily at high temperatures, and the presence of the warm reoxidised clay can sometimes be sensed beneath the cool reduction-fired iron-blue glazes. Where Ju ware clays were left unglazed they tended to fire to attractive grey-brown tones, traditionally described as 'the colour of incense ash'. Most Ju wares, however, were glazed overall, and the high refractoriness of the local body-materials allowed the wares to be set on multiple clay spurs during the glaze firing, without the ceramics distorting through pyroplastic effects. Overall glazing also discouraged reoxidation from spreading through the clay, beneath the glaze, at the end of the firing, *via* the foot-ring area; the neat 'sesame seed' scars left by spurs on the undersides of Ju wares have become a connoisseurial characteristic of the material.

In composition the Tzhu-chou clays were not unlike those used for Ju wares, but higher firing temperatures (*c.* 1,250–1,300°C), and neutral to oxidising atmospheres, created an off-white to cream material that appear outwardly different from the Ju body-ware bodies. Their general refractoriness could be similar, and was exploited in a similar manner by the potters, in this case by stacking many Tzhu-chou wares

[251] Wood *et al.* (1989), pp. 172–82.
[252] Chen Yaocheng *et al.* (1988), pp. 5–41.

Table 27 *Northern high-firing clay bodies: Shang dynasty to the Chin dynasty*

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	Total
Early northern whitewares									
Shantung *kuei* vessel, Neolithic[a]	63.0	29.5	1.5	1.6	0.7	0.8	1.5	0.2	98.8
Shang whiteware[b]	51.3	40.8	2.2	1.1	1.6	0.5	0.5	0.7	98.7
Shang whiteware[c]	57.2	35.5	0.9	1.2	0.8	0.5	2.3	1.3	99.7
Northern porcelains[d]									
Hsing body, Lin-chheng, Thang	69.9	25.1	0.6	0.2	0.9	1.6	0.9	0.9	100.1
Hsing body, Nei-chhiu, Thang	68.0	27.0	0.6	0.3	0.8	1.5	0.9	0.9	100.0
Hsing body, Lin-chheng, Thang	67.6	28.5	0.75	0.4	0.6	0.7	0.75	0.2	99.5
Ting body, Five Dynasties	61.2	32.9	0.6	0.6	3.4	0.9	1.25	0.1	101.0
Ting body, Northern Song	62.0	31.0	0.5	0.9	2.2	1.1	1.0	0.75	99.5
Ting body, Chin	59.2	32.7	0.75	0.7	0.8	1.1	1.7	0.3	97.3
Thang san-tshai *bodies*									
Kung-hsien *san-tshai* body[e]	63.8	29.8	0.9	1.4	1.6	0.6	0.7	1.2	100
Yao-chou *san-tshai* body[f]	65.9	27.85	1.2	1.15	1.5	0.5	1.3	0.5	99.9
Northern stonewares[g]									
Ju ware body, Northern Sung	65.3	27.7	1.2	2.2	0.6	0.4	1.9	0.2	99.5
	64.1	29.4	1.1	2.0	0.5	0.4	1.6	0.3	99.4
Lin-ju body, Chin	64.5	29.8	1.4	1.8	0.5	0.7	2.2	0.3	101.2
Yao-chou body, Northern Sung	64.4	27.4	1.2	2.5	0.8	0.7	2.7	0.3	100
Chün ware body, Northern Sung[h]	64.8	30.0	1.2	1.7	0.4	0.3	1.6	0.5	100
Tzhu-chou ware, Northern Sung[i]									

[a] Luo Hongjie (1996), database.
[b] From Yang Gen *et al.* (1985), pp. 30–1.
[c] *Ibid.*
[d] Hsing ware analyses from Chen Yaocheng *et al.* (1989a), p. 224; Ting body analyses from Li Guozhen & Guo Yanyi (1986), p. 136, table 1.
[e] Li Guozhen *et al.* (1986), p. 77, table 1.
[f] *Ibid.*
[g] Guo Yanyi & Li Guozhen (1986b), p. 154, table 1 (Ju, Lin-ju and Yao-chou).
[h] Yang Wenxian & Wang Yuxi (1986), p. 209, table 5.
[i] Chen Yaocheng *et al.* (1988), p. 36, table 2.

Table 28 *Ju ware bodies*

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Total
Ju ware body 1	65.0	28.1	1.4	1.96	1.35	0.6	1.4	0.15	-.-	-.-	100.0
Ju ware body 2[a]	65.3	27.7	1.2	2.2	0.6	0.4	1.9	0.2	-.-	0.1	99.6
'Alexander bowl' in the British Museum[b]	62.5	31.4	1.3	1.5	0.9	0.5	1.3	0.5	-.-	-.-	100.1

[a] Guo Yanyi & Li Guozhen (1986b), p. 154, table 1.
[b] Pers. comm. Ian Freestone, the British Museum. The significance of this bowl to the northern Ju ware tradition is discussed in detail in Krahl (1993), pp. 72–5.

Table 29 *Tzhu-chou bodies and slips (Hopei province)*[a]

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	Total
Bodies										
N. Sung Kuan-thai and Pheng-chheng	64.3	30.0	1.2	1.7	0.4	0.3	1.6	0.5	0.01	100.0
N. Sung Tzhu-chou	64.2	29.0	1.3	2.2	0.3	0.4	2.15	0.3	-.-	99.9
Chhing Tzhu-chou	65.1	28.1	1.5	2.2	0.6	0.4	2.3	0.3	0.04	100.5
Slips										
N. Sung Tzhu-chou slip	54.2	37.3	0.9	1.0	2.7	0.2	1.8	0.8	-.-	98.9
Chhing Tzhu-chou slip	53.0	36.4	1.4	1.1	1.0	0.3	2.5	0.1	-.-	95.8
Shang whiteware[b]	57.2	35.5	0.9	1.2	0.8	0.5	2.3	1.3	-.-	99.7
Shang whiteware	57.7	35.1	1.0	1.6	0.8	0.6	2.2	1.05	-.-	100.1

[a] All Tzhu-chou analyses from Chen Yaocheng *et al.* (1988), p. 36, table 2.
[b] Yang Gen *et al.* (1985), p. 30.

one above another in the kiln. The stacks were again often supported on clay spurs, but of a cruder style to those used with Ju wares.

White slips were used to 'improve' the Tzhu-chou clays, and also as a useful grounds for painted and carved decoration. These whiter clays were close relations of those used for Shang whitewares (see Table 29). Indeed the important Tzhu-chou kilns of Pheng-chheng and Kuan-thai were only some 30 kilometres north of An-yang itself.

In the Thang dynasty the stoneware clays used for celadon-making at the Huang-pao site were dark-firing and rather coarse, and contained 3–4% iron oxides. The ingredients were poorly mixed, and at least two clays (one of which was high in iron and calcia) can be distinguished under strong magnification. Pale slips were often used on Huang-pao Thang dynasty wares to improve the clays' appearances, but

Table 30 *Yao-chou stoneware bodies and Yao-chou Ni-chhih 泥池 clay*[a]

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Total
Thang dynasty Huang-pao body	63.65	28.4	1.3	2.8	0.9	0.8	1.8	0.15	0.03	0.25	100.1
Slip on Thang dynasty body	63.1	31.0	1.35	1.2	0.7	0.7	1.8	0.15	0.01	0.1	100.1
Five Dynasties body	64.6	29.0	1.5	2.4	0.9	0.45	1.9	0.06	0.0	0.05	100.9
Slip on Five Dynasties body	64.7	30.2	1.5	0.9	0.8	0.3	1.4	0.05	0.01	0.1	100.0
Northern Sung dynasty body	66.0	27.6	0.9	1.7	0.55	0.4	2.5	0.2	0.0	0.1	100.0
Ni-chhih clay, fired	67.7	26.8	0.9	1.2	0.3		2.3	0.1	0.01		99.3

[a] Rastelli *et al.* (2002), pp. 181–5, tables 2–6.

the slips' titania levels gave yellowish rather than white effects.[253] The compositions of the white slips used on Thang and Five Dynasties Yao-chou wares are closely related to Yao-chou whitewares of the same period and many of the oxidised white-slipped stonewares of the period appear to be 'economy' versions of true Yao-chou whitewares.[254] A similar mottled microstructure can be seen in the bodies of early +10th-century Yao-chou wares. These too are relatively iron-rich, and often slipped, but reduction-fired versions of these wares often show fine bluish celadon glazes, with their qualities enhanced by their white-slipped grounds.

Clay preparation was greatly improved in the Northern Sung dynasty when shallow circular troughs, some 7 metres in diameter, 40–45 centimetres wide and 7 centimetres deep, made from arkose sandstone and with rolling millstones set on their edges, were used to crush the dry clays.[255] This thorough crushing was probably necessary because of the hard shaley nature of the fireclay-like materials used at the site, traditionally described as *Ni-chhih* 泥池 clays (see Table 30). Once powdered, the clays were blended with water in large horse-shoe-shaped vats to make a slip, and this permitted wet sieving before dewatering.[256] The textures of finer examples of Sung dynasty Huang-pao stonewares reflect this careful preparation, and any separate clays used in the body recipes are no longer discrete.

[253] Rastelli *et al.* (2002), p. 187.
[254] *Ibid.*, p. 192.
[255] Excavated at Thung-chhuan Middle School No. 4. in 1984–6. See Tu Pao-Jen & Cho Chen-Hsi (1987), pp. 15–25, and Zhuo Zhenxi (1998), p. 3.
[256] Zhuo Zhenxi (1998), p. 3.

The adoption of coal as fuel at Yao-chou during the Northern Sung period, combined with higher firing temperatures, promoted the maturation of the local lime-alkali glazes, but must have lengthened the time that the Yao-chou glazes were held at high temperatures. This caused a white layer of fine bubbles and anorthite crystals to form at the glaze-body interface of +11th- to +14th-century Yao-chou celadons. This in turn had the effect of enhancing carved and impressed designs, while making the use of white slips redundant.

DEVELOPMENT AND GROWTH OF SOUTHERN PORCELAIN

DEVELOPMENT OF SOUTHERN WHITEWARES

At the same time as carved and press-moulded celadon wares were being developed at the Huang-pao kilns in the +10th century, another major ceramic tradition was emerging in south China in the form of southern white porcelain. The pattern for whiteware development already outlined for north China (that is from materials closely related to Neolithic and Bronze Age whitewares) was rather different to the process that took place in the south.

In north China, Neolithic whitewares were made from two types of material: pale fusible earthenware that fired creamy-buff rather than white, and a whiter-firing refractory clay. The first type was highly calcareous and melted easily at high temperatures. The kaolinitic whitewares, by contrast, were immature pale stonewares, and it was these materials that provided the basis for later northern high-temperature ceramics, including porcelains. In south China, however, two very different whiteware clays have been identified from the Neolithic period. One is an unusual high-magnesia material, and the other is a low-iron siliceous stoneware. Wares made from both clay-types have been found at the Chih-chiang 枝江 site in Hupei province, and a slightly different (higher calcia) style of magnesia-rich whiteware has also been excavated from the Neolithic Thung-hsiang 桐鄉 site in Chekiang province.

The high-magnesia southern whitewares are odd materials in that they are essentially hydrated magnesium silicates, rather than true clays, and are good illustrations of how non-clay platy materials can serve as effective clay substitutes. No examples have been recorded later than the Neolithic era and their use seems confined to this early period. Nonetheless, the high-magnesia whitewares from Hupei province were potentially refractory, and had some affinities with English 'soapstone' Worcester porcelain of the later +18th century (see Table 31), although the material seems never to have been used as a porcelain body in China. Southern Neolithic whitewares made from low-iron siliceous clays are more familiar materials. They are essentially underfired southern stonewares and their use in Hupei province anticipated many thousands of years of stoneware production in southern China.

The differences in titania contents (1.0 and 0.2% TiO_2) between the Hupei Neolithic whiteware and the much later Hupei porcelain may seem negligible, particularly as the other oxides are in such close agreement. But titania levels nonetheless constitute the main difference between low-iron southern stonewares and true porcelains. A maximum of about 0.2% TiO_2 seems typical for true southern porcelains, which places the Neolithic whiteware from Hupei province well within the

Table 31 *Southern Neolithic whitewares*[a]

a) High-magnesia types

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	ig. loss	Total
Chih-chiang, Hupei, Neolithic	66.5	3.7	0.01	1.6	0.4	24.0	0.15	0.04	0.03	0.2	3.45	100.1
Thung-hsien, Chekiang, Neolithic	52.1	5.5	0.4	2.0	9.5	20.0	0.2	0.1	0.1	3.8	6.4	100.1
Thung-hsien, Chekiang, Neolithic	54.3	6.5	0.3	3.8	7.75	17.0	0.8	0.1	0.1	3.4	6.2	100.3
Worcester porcelain *c.* +1760[b]	72.3	3.4	<0.2	0.4	1.9	11.0	3.3	1.4 (+ PbO 5.7)				98

[a] All analyses of Chinese Neolithic whitewares from Luo Hongjie (1996), database.
[b] Freestone (2000), p.20, table 1.

b) White siliceous stoneware type, compared with an example of Northern Sung *ying-chhing* ware from Hupei province

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Total
Chih-chiang, Hupei, Neolithic	69.7	22.1	1.0	1.5	0.2	0.8	3.1	0.1	0.01	0.06	98.6
Ying-chhing, Hupei, Northern Sung	71.8	22.0	0.2	0.7	0.8	0.3	3.8	0.1	0.04	0.2	99.9

Table 32 *Eastern Han dynasty glazed whiteware excavated from Vietnam*

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	Total
Eastern Han tripod vase excavated at Thanh-hoá[a]	78.9	14.85	2.5	1.6	0.1	0.1	1.15	0.6	0.03	99.83

[a] Desroches (1989), pp. 36–7.

underfired stoneware class. A similar high titania content also disqualifies a much later southern whiteware material, i.e. Han period glazed whitewares of southern Kuangtung province and northern Vietnam, from consideration as true ancestors of southern porcelain. These Eastern Han period wares from the extreme south of China were low in iron, but their titania levels could be as high as 2%, and their low potassium oxide contents suggest heavy tropical weathering (Table 32).

CHINESE PORCELAIN AND THE CITY OF CHING-TE-CHEN

The real beginnings for southern porcelain in China, so far as they can be assessed at present, occurred hundreds of years later than in the north, in the early +10th century. Particularly important was the Ching-te-chen 景德鎮 district of northern Chiangsi province, an area that later became the 'porcelain capital' of both China and the world. Because of the pre-eminent role played by Ching-te-chen in international ceramic history, a detailed survey of its economic and social development is included here.

THE PORCELAIN INDUSTRY AT CHING-TE-CHEN

Ching-te-chen has one of the most complete literatures of any ceramic-producing area in China. From primary literary sources, and from the large body of secondary literature that has grown up around these references, it is possible to glean considerable information about the operation and products of kilns, and the organisation of labour at Ching-te-chen (see also Part 1). A full econometric history, though, is not possible, for as Michael Dillon has noted: 'while there are adequate figures for imperial orders and tax liabilities . . . there are few for the amounts produced, costs, prices or wages.'[257]

Several accounts of the city have been written that stress economic aspects of production.[258] The present section of this volume incorporates aspects of this research, and also bases its findings on available primary and secondary historical and literary sources. For this reason, its content favours imperial kilns, and names and events concerned with them, rather than a broader economic or historical summary. The vivid picture of the industry that emerges helps to place the great technological achievements of Ching-te-chen in perspective.

OFFICIAL CONTROL OF THE POTTERY INDUSTRY AND THE IMPERIAL KILNS AT CHING-TE-CHEN

In China, until the Thang period, direct government regulation of ceramic production was mainly concerned with building materials, vessels for ritual and items for burial (see pp. 1–19). Changing nomenclature delineated official structure of the pottery industry. For example, in the Northern and Southern Dynasties the terms *Thao-kuan Wa-shu* 陶官瓦署 (Government Pottery Works), and *Chen-kuan Shu*

[257] Dillon (1976), p. 8.

[258] Anon. (1959a); Dillon (1976); Dillon (1978); Yuan Tsing (1978); Liang Miao-Thai (1991). Their bibliographies provide numerous further references.

甄官署 (Pottery Office) subordinate to the Chamberlain for Palace Revenues (*Shao-fu* 少府), were used. In the Northern Chhi period the role of the Pottery Office was to regulate building requisites and the manufacture of large containers for use as cisterns. In the Northern Chou period a low-ranking official called Ordinary Serviceman (*chung-shih* 中士) was responsible for making pottery ritual vessels.[259] In the Sui dynasty the Pottery Office came under the Court for the Palace Revenues (*Thai-fu Ssu* 太府寺), while in the Thang dynasty it reported to the Directorate for the Palace Buildings (*Chiang-tso Chien* 將作監). Thang dynasty references to the activities of the Pottery Office were fairly explicit. For example, the institutional compendium *Thang Liu Tien* (Institutes of the Thang dynasty, +738) noted that: 'In the affairs of tiles and bricks there are standards for size and quality, as there are for all jars and cisterns, and objects for burial.'[260] *Chiu Thang Shu* (Old History of the Thang dynasty, +945) said that: 'The Pottery Office is responsible for stone and ceramic works, the supplying of musical stones, columns of figures and animals, jars and cisterns, and objects for burial.'[261]

During the Sung era the name *Yao-wu* 窯塢 (Kiln Office) was standard, while in the Chin dynasty usage reverted to *Chen-kuan Shu* 甄官署. By the Yuan period the title *Yao-chhang* 窯廠 (Pottery Works) was employed for the units at Ta-tu 大都, the Mongol capital.[262]

The first evidence of a kiln centre whose main function was to serve the imperial court, occurred at Ching-te-chen in the south. The establishment of an official unit there satisfied the need for palace ware that had been met in earlier times by selecting fine wares from kilns in both north and south China. For example, in the Thang dynasty the Pottery Office exacted tributes of Yüeh ware from Chekiang province (see pp. 272 and 530). In the Five Dynasties period there was evidence that ceramic items were accepted by the government in lieu of tax, in the same way that tea was calculated as a tax equivalent.[263] By the Sung dynasty a number of kilns supplied the court with tribute wares, among them producers at Jao-chou (the region in which Ching-te-chen is situated). Porcelain warehouses (*tzhu-chhi khu* 瓷器庫) in several locations stored assembled tribute wares, before they were sent on to court.[264]

Ching-te-chen was known as Chhang-nan[265] 昌南 until it became a market town (*chen* 鎮) and supplied porcelain to court in the Ching-Te reign period taking the name of Ching-te-chen in +1004.[266] The administrative unit *chen* was smaller than a county (*hsien* 縣) in the Sung period, but it was large enough to encompass a large population and thus to reap significant tax revenues.[267] An official was dispatched

[259] Huang Pen-Chi (1965), p. 82. Hucker (1985), p. 192.
[260] *Thang Liu Tien*, ch. 23, p. 13. Hucker (1985), pp. 140, 477.
[261] *Chiu Thang Shu*, ch. 58, p. 1896. A similar reference is found in *Hsin Thang Shu*, ch. 48, p. 1274.
[262] Huang Pen-Chi (1965), p. 82. For further details of nomenclature and organisation, see Hucker (1985), pp. 121, 489, 576–7.
[263] *Sung Shih*, ch. 183 ('*Shih Huo Hsia*, 5'), p. 4477. Sung *et al.* (1995), p. 10. Ts'ai (1996), pp. 112, 114, 125.
[264] *Sung Hui Yao Chi Kao* ('*Shih Huo*') 52:37.
[265] [Town] to the south of the [river] Chhang 昌江.
[266] *Ching-te-chen Thao Lu*, ch. 5, p. 1b.
[267] *Shih Wu Chi Yüan*, ch. 7, p. 9. *Sung Hui Yao Chi Kao* ('*Chih Kuan*'), 48:92.

from court to take control of Ching-te-chen, and he was responsible for law and order, the control of fuel quantities (*yen-huo* 煙火, lit. 'chimney smoke and fire') for kilns, the sending of porcelain levies to the porcelain warehouses and the collecting of taxes.[268] In the 5th year of the Yüan-Feng reign period (+1082) a government office (*Po-i Wu* 博易務) was set up to deal with trade.[269] The fortunes of officials and administrators at Ching-te-chen have been fraught with difficulties, however, from that time down to the present day. By the early +13th century this office had been disbanded, and the job of kiln inspector (*yao-hsün* 窯巡) terminated. Nonetheless, strict official quality-control was maintained, with production of three grades of porcelain (top, middle and low). Cheating on quality-control resulted in punishment. If any irregularity was discovered, irrespective of who was culpable, everyone, from the sales officer down to the delivery men, would be punished.[270]

It was in the Yuan dynasty that direct imperial intervention caused a new organisation called *Tzhu-chü* 瓷局 'Porcelain Bureau' to be established.[271] At that period imperial wares were only supplied when orders came down from the capital.[272] The site chosen for the depot was *Chu-shan* (Pearl Hill 珠山) at what was then the southern-most edge of the city, a location that was subsequently taken over and enlarged by the Ming.[273] The Porcelain Bureau was set up in +1278 under the direction of a principal (rank 9a) and deputy officer, to manage the making and firing of porcelain, the processing of lacquer, horsehair, coir rattan, straw hats etc. Quantity, design, colour, use, restrictions on private production, official posts and production difficulties at the Bureau were summarised in the Yuan dynasty official history.[274] Many officials employed at the Yuan Court were from the Islamic West, and the first Supervisor of the Porcelain Bureau was Nepalese, while some of his successors were Persian or Mongolian.[275] In +1295 the bureau was expanded and its director raised in rank.[276] In +1324 it was incorporated into the local tax bureau and the Supervisor appointed, one Tsang Thing-Feng 臧廷鳳, immortalised his appointment in the preface to *Fu-liang Hsien Chih* (Gazetteer of Fu-liang county, +1682):[277]

[268] *Sung Hui Yao Chi Kao* ('*Chih Kuan*'), 48:92 ('*Fang Yü*'), 12:18–21.

[269] *Chung-Kuo Li-Tai Shih-Huo Chih Cheng-Pien* (1970), vol. 1, p. 462.

[270] *Thao Chi*, included in the +1682 and +1742 editions of *Fu-liang Hsien Chih*; references in this volume are made to the complete text reproduced by Pai Khun (1981), here p. 40.

[271] Shih Ching-fei (2001), p. 32, emphasises that the Fu-liang *Tzhu-chü* was only a sub-bureau of another Directorate in the court system, and that it was headed by a lowly commissioner-in-chief rank 9a. From this, she deduces that porcelain was not especially valued by the Yuan court, her thesis arguing that the Mongols esteemed precious metals, bronze and hardstones, above porcelain from Ching-te-chen.

[272] *Ching-te-chen Thao Lu*, ch. 5, p. 2a.

[273] Liu Hsin-Yüan (1993), p. 36. Liu Hsin-Yüan directed a team that excavated the imperial kiln site at Ching-te-chen in the +1980s and +1990s. A number of luxurious and unusual porcelain items came from the Yuan dynasty strata, but no kiln remains or utensils were found. It is therefore uncertain whether the Porcelain Bureau had its own factory in that period, or whether it assembled choice items from private kilns.

[274] *Yuan Shih, Chih* 38, ch. 88, p. 843. *Ta Yuan Sheng Cheng Kuo Chhao Tien Chang*, ch. 7, p. 36/114. Cf. Tsao Chien-Wen (1993), p. 28 and note 4.

[275] Liu Hsin-Yüan (1993), p. 36.

[276] Harrison-Hall (2001), p. 22.

[277] *Fu-liang Hsien Chih* ('*Hsü*'). Hucker (1985), p. 531.

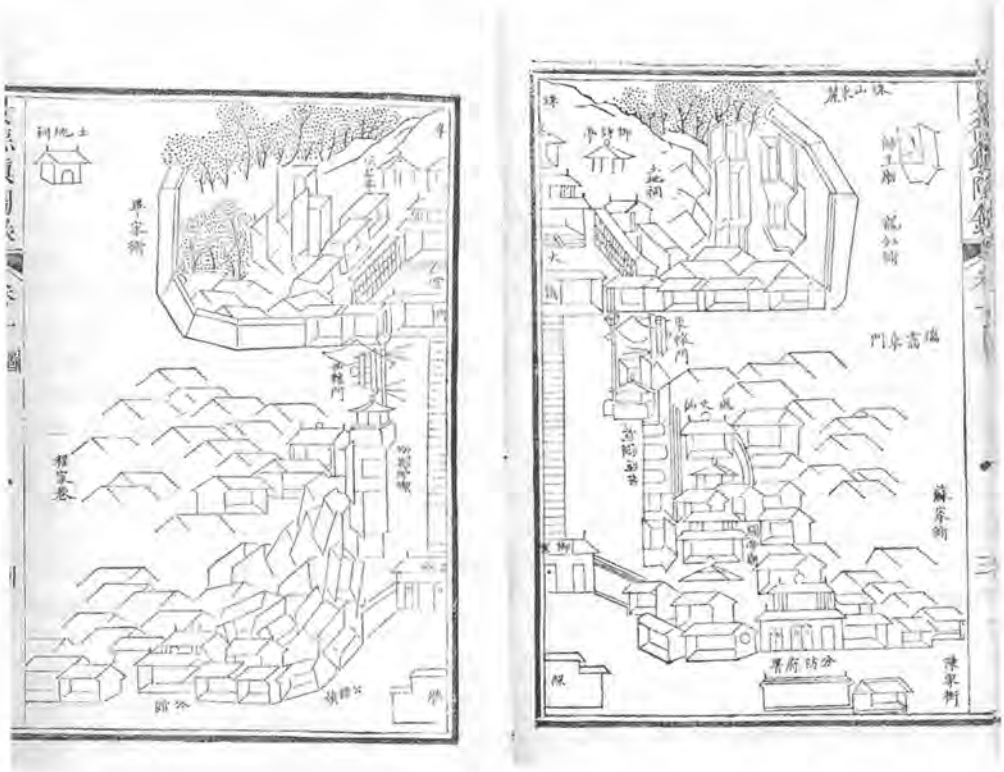


Fig. 41 Ching-te-chen and the imperial factory on Chu-shan, from *Ching-te-chen Thao Lu* (+1815)

I arrived to take up my post in the third month, and received my orders from Duke Tuan 段公 (the Assistant Brigade Officer [*Tsung-kuan* 總管] of Jao-chou territory Tuan Thing-Kuei 段廷圭). I was to manage pottery affairs in the region.

After +1328 the Provincial Governor acted as Supervisor.[278]

In +1352–4 the vestiges of the Yuan dynasty army were repelled from the city, which was sacked in the process, and business destroyed.[279] At the start of the Ming dynasty in +1369, an imperial porcelain factory was built on Chu-shan.[280] We do not know the exact size or layout of the +14th-century factory, but by the +16th century it consisted of a central hall with three reception rooms; a studio and residence

[278] *Ching-te-chen Thao Lu*, ch. 5, p. 2a.

[279] Liang Miao-Thai (1991), p. 13.

[280] The date of the founding of an official kiln has been debated. *Ching-te-chen Thao Lu*, ch. 1, p. 1a, and ch. 5, p. 3a, gives the second year of Hung-Wu (+1369) for the foundation. Medley (1966) was among many authors arguing for an alternative date of +1402, but subsequent archaeological excavation of Hung-Wu imperial wares support the earlier date, i.e. +1369. Further confirmatory evidence comes from an excavated roof tile bearing the name of the man who was appointed Magistrate of Fu-liang county in +1369, see Liu Hsin-Yüan (1993), p. 38. Recently, Wang Kuang-Yao (2001) has argued for a founding date of +1426.

at the back for the Superintendent; a total of 23 large storehouses to east and west; 58 furnaces including those specially for firing dragon cisterns, high-temperature kilns and muffle-kilns for overglaze-decorated wares; three temples inside the factory grounds and one outside; two wells; and eight rooms for the potters to rest in.[281]

After +1369, an official Superintendent was stationed at the imperial factory to supervise manufacture and to dispatch orders to the capital. In +1384 it was specified that if imperial orders were large, personnel were to be brought from the capital and new kilns set up. If orders were small, they could be farmed out to other kilns in the area around Ching-te-chen.[282] At the beginning of the Cheng-Te reign period, the factory was rebuilt and became known as the Imperial Vessels Factory (*Yü-chhi Chhang* 御器廠) for the first time.[283] A tax office for the imperial factory was reinstituted, to regulate income from imperial wares.[284] The 36th year of the Wan-Li reign period (+1608) was the last year of the Ming dynasty in which imperial wares were made at Jao-chou. The imperial factory closed down and its skilled workers dispersed to work for private businesses. Evidence for this was provided by a stele excavated at Ching-te-chen. Its dedicatory inscription by a eunuch official, dated +1637, records that after +1608 potters from the imperial kiln were employed at independent kilns instead.[285]

During the troubled years of the transition from Ming to Chhing dynasties, pottery production continued at private kilns alone. In +1645 soldiers of the Chhing army reached Jao-chou,[286] but it was not until +1654 that the remnants of the Ming imperial factory were reorganised and renamed.[287] In +1680 the Khang-Hsi Emperor instigated an enquiry into the state of the pottery industry, and the setting up of an imperial factory. This new factory thrived for 100 years under the direction of officials appointed from Peking. After +1787 the post of resident Superintendent was no longer recruited from Peking, and instead the Controller of the Chiu-chiang customs, the vice-prefect of Jao-chou and the deputy magistrate of Ching-te-chen assumed joint responsibility for appointments and production at the imperial kilns. This led inevitably to a slackening in standards, and to looser links with the centre of power in Peking. From +1854 the Thai-phing 太平 rebellion led to turmoil in the city, and great destruction including that of the imperial factory in +1855.[288] Even greater devastation was caused when Thai-phing troops engaged in battle with imperial soldiers during +1861. They were victorious, but were shortly afterwards

[281] *Chiangsi Sheng Ta Chih* (1597 edn), ch. 7, pp. 3a–4a. A slightly less-detailed account is given in *Chiangsi Thung Chih* (1880 edn), ch. 93, pp. 3a–4a.
[282] *Ta Ming Hui Tien*, ch. 194, p. 1a/2631.
[283] *Chiangsi Sheng Ta Chih* (1597 edn), ch. 7, p. 2a. *Ching-te-chen Thao Lu*, ch. 5, p. 3a.
[284] *Jao-chou Fu Chih* (1872 edn), ch. 3.3, p. 51a.
[285] Liu Hsin-Yüan (1993), p. 44.
[286] Liang Miao-Thai (1991), p. 118.
[287] The name change was from *Yü-chhi Chhang* ('imperial vessels depot') to *Yü-yao Chhang* 御窯廠 ('imperial ware factory'). Sung Po-Yin *et al.* (1995), p. 11.
[288] *Chiangsi Thung Chih* (1880 edn), ch. 93, p. 8a.

defeated at Le-phing 樂平 and driven out of the district by +1864. This caused temporary ruin to the ceramic industry, and though the imperial factory was rebuilt in +1866 by a new superintendent Tshai Chin-Chhing 蔡錦青,[289] it never regained its pre-eminent position. In +1864 Tshai had responded to an urgent request from court for ritual vessels for the Imperial Ancestral Temple, saying that workers had fled the area, bandits were rife and it was difficult to recruit new labour. Furthermore, many skills had been lost or forgotten.[290]

In +1882 Francisque Scherzer reported the imperial factory buildings in ruins, and a demoralised workforce paid at little more than the general rate available in Ching-te-chen.[291] By +1910 Chhen Liu 陳瀏 lamented in his *Thao Ya*: 'Today our Chinese porcelain is in sad decline, the craftsmanship is no good and the material is rough and crude.'[292] It was in that year before the Chhing dynasty ended, that a new, partly state-run and partly privately capitalised factory was established. The *Chiangsi Tzhu-yeh Kung-ssu* 江西瓷業公司 (Chiangsi Porcelain Company) marked the end of the imperial kiln, though this was only the beginning of development at Ching-te-chen in the +20th century. A long period of decline was not immediately halted. Proper collection of statistics on the industry only started in +1928, when 114 large kilns were in operation employing 2,226 men. Deep recession was apparent during the Sino-Japanese war, and by +1936 only 72 kilns were in operation, employing 1,512 workers.[293] The Japanese occupation wreaked near-total destruction at the kilns in the late +1930s, repeating events that had occurred with the fall of the Ming dynasty in the mid +17th century, and the Thai-phing Rebellion in the mid +19th century. Matters did not significantly improve until after the revolution of +1949, when the state reassumed control and set about restoring production. By that time, less than a third of the great high-temperature kilns were still functioning.[294] By the mid +1950s Russian scientists reported that about 70 large kilns were again in operation, firing at the rate of five to six times per month.[295]

Official Control of the Imperial Factory: Taxes, Requisitions and Problems

Official control of ceramic manufacture realised two benefits; top-quality products, and revenue from taxes. It is not clear when tax on ceramics began. At least two authorities suggest that the development of the porcelain industry was inspired by prohibitions on production and use of bronze wares in the Thang dynasty.[296]

[289] Bushell (1896), pp. 152–3, and Kuan Shan-Ming (1983), pp. 5–6, 20–1, who both include a description of the layout of the +1866 factory reconstruction. See also Wright (1920), p. 21.
[290] *Nei Wu Fu Tsou Hsiao Tang* for the 3rd year, 8th month, 26th day of Thung-Chih. Report of the Provincial Governor of Chiangsi for the 13th year of Thung-Chih.
[291] Scherzer (1882), quoted in Tichane (1983), p. 191.
[292] *Thao Ya*, ch. 1, p. 13b, Sayer (1959), p. 25.
[293] Anon. (1959a), pp. 270, 287–8.
[294] Mei Chien-Ying (1955), pp. 14–15.
[295] Efremov (1956), p. 492.
[296] Anon. (1959); Chhen Wan-Li (1976).

However, named commodities required for taxation did not include ceramics at that time.

At Ching-te-chen, porcelain taxation started when imperial patronage was bestowed in +1004. From that time until +1077 taxes were light, and were sent on to the county (*hsien* 縣) of Fu-liang in which Ching-te-chen was located. There they were counted, and paid over to Jao-chou, the prefecture (*chou* 州) in which Fu-liang and other districts were situated. After +1077 business flourished to the extent that each locality within Ching-te-chen paid equal taxes to those of a whole county, an amount of 3,337 *kuan* 貫,[297] and the money was paid directly to the prefecture. By the Southern Sung dynasty, taxation had increased ten-fold, indicating a booming ceramic industry.[298]

Occasionally exemptions were granted. For example, in +1108, porcelain was excused from taxation, along with tiles, charcoal, wood fuel, fruit, vegetables, fish, chicken, cereals, shoes and commoners' clothing.[299] This was an unusual dispensation, for kilns and their products were raising large revenues. *Thao Chi* informs us that taxation was levied according to the firing capacity of the kiln, the size of kiln being recorded by officials. Areas not specifically used for firing vessels were exempt from taxation. They were the fire chamber (*huo-thang* 火堂), fire corridor (*huo-chan* 火棧), firebox (*huo-wei* 火尾) and observation holes that also gave their name to expert supervisors (*huo-yen* 火眼).[300] By the Yuan period Ching-te-chen had become a customs point and there was regular taxation of porcelain.[301] At the start of the Ming dynasty taxation was lowered, in order to revive industry and promote production.[302]

Funds for the porcelain production that raised such useful taxes were borne by the provincial authorities in the Ming dynasty, by means of silver and goods in kind, for example, grain.[303] In the early Chhing dynasty funds for porcelain production were still allocated from the provincial treasury, but after +1671 it became the responsibility of government, and no longer required local taxation.[304] The problem of funding the ceramic industry so that it in turn could yield taxes was partially solved by diverting funds from internal customs revenue. After +1727 costs were paid through customs tax,[305] and Superintendents of the imperial porcelain factory had also assumed responsibility for customs barriers on the Grand Canal in Chiang-nan. There were eight customs collecting points from Peking down to

[297] A *kuan* was a string of 1,000 cash.

[298] Liu Hsin-Yüan (1991), pp. 8–15.

[299] *Chung-Kuo Li-Tai Shih-Huo-Chih Cheng-Pien*, vol. 2, p. 457. There were many improvements to the taxation system on the land during the Northern Sung period.

[300] Pai Khun (1981), p. 38. See Liu Hsin-Yüan (1991), p. 6.

[301] *Chung-Kuo Li-Tai Shih-Huo-Chih Cheng-Pien*, vol. 2, pp. 593–7, 739–40.

[302] Feng Hsien-Ming *et al.* (1982), p. 357.

[303] For example, in the 33rd year of Chia-Ching (+1554), funds for ceramic materials were provided by the Provincial Administration Commission (*Pu-cheng Ssu* 布政司, *Chiangsi Sheng Ta Chih* (1597 edn), ch. 7, p. 44b, see Hucker (1985), p. 391.

[304] *Chiangsi Thung Chih* (1732 edn), ch. 27, p. 33.

[305] *Ta Chhing Hui Tien*, ch. 1190, p. 1.

Chiu-chiang 九江 along the Grand Canal, which opened for traffic in +1415.[306] Income from the customs barriers must have been considerable. For example, the Chiu-chiang Customs came into being in +1429, not to collect duties on goods but to tax junks according to capacity. In +1563 a branch office was opened at the mouth of Pho-yang Lake 鄱陽湖, which needed to be moved again in +1724 owing to silting-up of the lake bed due to lack of dredging.[307] In +1727, 8,000 taels out of revenue from the Huai-an 淮安 customs barrier was reserved for porcelain production.[308] In +1739 the source of payment was switched to Chiu-chiang customs barrier,[309] at the junction with the Yangtze river and much closer to Ching-te-chen. There continued to be problems with the system, for although production costs in that year were 20,000 catties of silver, only 10,000 had been allocated by the local customs bureau and additional funding had to be requested via the court in Peking.[310] The dual duties as Supervisor of the imperial factory and of customs became too great for one individual to bear, as petitions to the court from Superintendents begging to be relieved of customs duties testify.

In addition to tax revenue, porcelain made at the imperial factory provided top-quality utensils for the huge royal household. Several departments competed to order and supervise production, sometimes with deleterious results. In the Yuan dynasty, orders for quantity and design of porcelains came from the Imperial Manufactories Commission (*Chiang-tso Yüan* 將作院).[311] That agency supervised an abundance of artisans in the manufacture of gold, silver, jade and other luxury utensils for palace use.[312]

At the onset of the Ming dynasty, chief responsibility for palace orders belonged to departments within the extensive Ministry of Works *Kung fu* (工部). However, other interest-groups frequently intervened, and one can discern conflicting remits in the supervision of imperial porcelain production. On the one hand, civil servants from different sections of the Ministry of Works were assigned from Peking to supervise manufacture, and later in the period local prefectural officials were used in the same way. On the other hand, eunuch officials from various departments of the imperial palace and government departments were sent to supervise and to guarantee special orders. The problem of eunuch power during the Ming dynasty has been studied.[313] The tension that existed between the 'inner court' (eunuch officers from the palace) and the 'outer court' (scholarly bureaucrats from central government)[314] led to an erratic system of control. Official wares from Ching-te-chen were

[306] Ray Huang (1969), pp. 99, 107.
[307] Wright (1920), pp. 120–1.
[308] Anon. (1959a), p. 111, citing *Fu-liang Hsien Chih*.
[309] *Ching-te-chen Thao Ko* (1823), p. 9a.
[310] Fu Chen-Lun & Chen Li (1982), pp. 31–2.
[311] The Imperial Manufactories Commission was set up in +1293, *Yuan Shih*, ch. 88, pp. 2225–6.
[312] *Ta Yuan Sheng Cheng Kao Chhao Tien Chang*, ch. 7, p. 36/114. Cf. Tshao Chien-Wen (1993), p. 28 and note 4. Hucker (1985), p. 141.
[313] Hucker (1958); Crawford (1961); Ray Huang (1969); Yang Lien-Sheng (1969); Shih-San Henry Tsai (1996).
[314] Hucker (1958), p. 21.

all destined for the palace, and Ming emperors, who enjoyed supreme power, often employed eunuchs as a rival power-group to the civil bureaucracy in order to hasten production or increase orders. Emperors frequently became frustrated with their civil servants, and bypassed them by sending eunuchs on procurement missions to Ching-te-chen. Many battles were fought when shortages in the supply of palace goods (including porcelain) occurred. The Ministry of Works had to fund extra orders placed by eunuchs, which often comprised very large quantities of porcelain, or complex forms, or extra-large vessels, and thus could be very expensive.

We should recognise that official historiography, composed by bureaucrats, adopted a particular view of events. It tended to present eunuchs as being irredeemably corrupt, and the cause of many problems at the kilns. Thus chronicles of Ching-te-chen were littered with the names of men who oppressed the workforce and amassed personal fortunes, and contained frequent complaints against eunuch management by the civil administration.[315] In spite of this bias, some credence must be given to the view that control from Peking allowed repeated abuses of power. Incidents culled from the historical record are included here by way of illustration.

In +1398 imperial kiln manufacture was reconfirmed under the supervision of a eunuch official from *Ying-shan So* 營膳所 ('Construction Section') a minor unit in the Ministry of Works that superseded the Palace Buildings Office in +1392.[316] In the Hung-Hsi reign period, a junior eunuch called Chang Shan 張善 was dispatched to Jao-chou to supply and supervise the making of white porcelain vessels with dragon and phoenix designs for palace banquets.[317] He made an auspicious start by building a temple and extra storerooms, and offering prayer and sacrifices to the God of Kilns.[318] However, in +1427 he was dismissed from his official post, due to criminal offence.[319] Another account allots an even worse fate to Chang Shan – decapitation – on account of his cruelty and corruption.[320] After +1427 an official from the Construction Section supervised the most skilled work, but in the Cheng-Thung reign period the post was abolished.[321] In the first year of Thien-Shun (+1457) a eunuch official was again Superintendent at the imperial kilns[322] and during the reign period of Chheng-Hua eunuch officials were sent to Ching-te-chen.[323] In the 18th year (+1482) a high official petitioned the court to withdraw costly management by Peking-appointed supervisors, and was punished with banishment.

[315] Cf. Ray Huang (1974), pp. 8–11. Huang concludes that despite occasional abuses of power, eunuchs did not seriously interfere with government operation prior to the late Ming period. For eunuch power and Ching-te-chen, see also Shih-San Henry Tsai (1996), pp. 182–3, 185.

[316] Its staffing and specific responsibilities are not clear, see Hucker (1985), p. 583.

[317] *Chung-kuo Li-Tai Shih-Huo-Chih Cheng-Pien*, vol. 2, p. 942. *Ming Shih Lu*, ch. 9, p. 4a/0231, says that the Ministry of Works ordered white porcelain sacrificial vessels for altars.

[318] *Fu-liang Hsien Chih* (1682 edn), ch. 8, pp. 32a–b.

[319] *Chung-Kuo Li-Tai Shih-Huo-Chih Cheng-Pien*, vol. 2, p. 942.

[320] *Ming Hsüan-Tsung Shih Lu*, ch. 34, p. 4a/0863.

[321] *Jao-chou Fu Chih* (1872 edn), ch. 3:3, p. 51, citing *Chiangsi Sheng Ta Chih* (1597 edn), ch. 7, p. 3a.

[322] *Chiangsi Sheng Ta Chih* (1597 edn), ch. 7, p. 3a.

[323] *Ta Ming Hui Tien*, ch. 194, p. 4a/2632.

In +1485 local officials added their voice to the protest, and requested a temporary cessation of orders.[324] Finally, in the first year of the succeeding reign period (+1488), all officials in charge of ceramic manufacture were ordered to return to the capital.[325]

At the beginning of the Hung-Chih reign period a eunuch official was reappointed.[326] After +1507 an official called Liang 梁 reported on production but resided at court. At the end of the Cheng-Te reign period, in the 12th year (+1520) a eunuch Supervisor titled I Fu 伊輔 was appointed to help and was dispatched to Jao-chou.[327] Between +1530–71 and +1573–82 the post of Supervisor was taken on by the Assistant Prefects of Chiangsi's fourteen prefectures, each serving a one-year term in rotation. Finally in +1582 the Assistant Prefect of Jao-chou took up permanent station there.[328]

In +1597 a man called Shen Pang 沈榜 was appointed as Assistant Prefect of Jao-chou. His special brief was to manage ceramic production of imperial ware in private factories (see *Kuan-ta Min-shao* 官搭民燒 below),[329] and he swiftly availed himself of the opportunities of his lucrative position. By +1599 he had achieved national notoriety, being censored for corruption (holding back 20% of all funds paid out through his office), irregularity (selling government porcelain in personally owned stores) and immoral conduct (including incest and murder). Shen Pang was reprieved by personal intervention of a eunuch official at court, but after protests by government ministers, he petitioned to leave office in +1600.[330] Official corruption also affected the delivery of imperial porcelain, and allowed the theft of monies disbursed by the provincial treasury as wages.[331]

The troubles at the imperial depot were not over. Shen Pang had been replaced by the Assistant Prefect of Jao-chou Chhen Chhi-Kho 陳奇可, but in +1601 Chhen was arrested and replaced by a eunuch, a mining tax inspector called Phan Hsiang 潘相.[332] In +1602 Phan Hsiang's excessive demands (aided and abetted by a hanger-on called Wang Ssu 王四) caused mutiny among the potters and destruction of kilns. Assistant Prefect Chhen Chhi-Kho could only stand helplessly by.[333] By +1604 Phan had extended control. He used his connections in the mining industry to facilitate expansion of official kaolin mining on to land traditionally reserved for agriculture, causing great public concern.[334] In +1606, when the mining business was experiencing recession, Phan requested to go back to Ching-te-chen to manage kilns. In spite

[324] *Ming Shih*, ch. 14 ('*Hsien Tsung*: 2'), p. 100. This passage illustrates the tension imposed by eunuchs sent from court, with large orders for porcelain, and local officials. See also Liu Hsin-Yüan (1993), pp. 30, 70.
[325] *Ta Ming Hui Tien*, ch. 194, p. 4b/2632.
[326] *Chung-Kuo Li-Tai Shih-Huo-Chih Cheng-Pien*, vol. 2, p. 942. *Ta Ming Hui Tien*, ch. 194, p. 4b/2632.
[327] *Chiangsi Sheng Ta Chih* (1597 edn), ch. 7, p. 2a. *Ming Wu-Tsung Shih Lu*, ch. 194, p. 7a/3639.
[328] *Jao-chou Fu Chih* (1872 edn), ch. 3.3, p. 56b, here quoting *Fu-liang Hsien Chih*.
[329] *Chung-Kuo Li-Tai Shih-Huo-Chih Cheng-Pien*, vol. 2, p. 942.
[330] Goodrich & Fang (1976), vol. 2, pp. 1186–7.
[331] *Fu-liang Hsien Chih* (1682 edn), ch. 4, p. 45b.
[332] *Jao-chou Fu Chih* (1872 edn), ch. 3.3, p. 62.
[333] *Ming Shen-Tsung Shih Lu*, ch. 368, p. 6b/6886; ch. 369, p. 12a/6919.
[334] *Fu-liang Thao Cheng Chih*, in *Fu-liang Hsien Chih* (1851 edn), ch. 4, p. 2.

of his bad record, his request was granted,[335] and he was not recalled till +1620 when his mining taxes were lifted.[336]

During the early Chhing dynasty the role of Superintendent of the imperial factory did not cause so many problems as in the Ming.[337] In his preface to *Thao Shuo* (+1774) Chhiu Yüeh-Hsiu 裘曰修 expressed the somewhat over-optimistic view that:[338]

> Among eunuch officials who supervised production in the Ming dynasty, there were those who frequently demanded more than the official rate required. Thus workers were not adequately remunerated for their labour and the populace was in great distress. By contrast, under the present dynasty government officials are properly selected, and they allocate money according to going rates, or even in excess of that, so that the workforce is happy and every day several thousand potters are at work.

A few outstanding individuals did emerge in the management of the imperial factory. Technical supervision during the early Chhing was in the hands of Liu Yüan 劉源.[339] He was a Secretary at the Ministry of Justice, a Palace Provisioner and a talented painter, ink cake designer and carver, who produced several hundred designs for the imperial factory.[340] He was also Superintendent of Customs at Wu-hu 蕪湖 and Chiu-chiang. After +1680 Hsü Thing-Pi 徐廷弼 from the Storage Office (*Kuang-chhu Ssu* 廣儲司),[341] and Bureau Secretary Li Thing-Hsi 李廷禧, were in supervisory residence at the imperial factory. In +1683–8 Tsang Ying-Hsüan 臧應選 was assigned from the Bureau of Forestry and Crafts (*Yü-heng Ssu* 虞衡司)[342] as Superintendent, along with a calligrapher who wrote reign marks called Chhe Erh-Te 車爾德.[343] From +1705 to +1712 the imperial kilns were managed by Lang Thing-Chi 郎廷极 who gave his name to a range of ceramics known as 'Lang ware' that included court wares imitating Yung-Le period whitewares, Hsüan-Te period blue-and-white and Chheng-Hua period *tou-tshai* 斗彩. Most famous were Lang's production of rich copper-red glazed items, of a quality unmatched since the +15th century (see p. 568).[344]

From +1712 to +1726 various officials were assigned from the Imperial Household Department to supervise official porcelain.[345] Then in +1726 Nien Hsi-Yao 年希堯, a Manchu Bannerman, was appointed Superintendent from Peking. His duties

[335] *Ming Shen-Tsung Shih Lu*, ch. 419, pp. 2a–b/7927–8.
[336] *Fu-liang Hsien Chih* (1682 edn), ch. 4, p. 40b.
[337] Feng Hsien-Ming *et al.* (1982), p. 416.
[338] *Thao Shuo* ('*Hsü*'), p. 1a.
[339] Kerr (1986), pp. 16–17.
[340] Sung Po-Yin *et al.* (1995), pp. 11–12, 41.
[341] One of seven major units in the Imperial Household Department that controlled the Six Storehouses in the palace, including the Porcelain Storehouse, see Hucker (1985), p. 287.
[342] A bureau in the Ministry of Works that regulated hunting and food-gathering and provided the government with mountain and forest products, see Hucker (1985), p. 591.
[343] *Ching-te-chen Thao Lu*, ch. 2, pp. 1a–b. Chhe Erh-Te was a Manchu, see Sawyer (1951), p. 11. *Chiangsi Thung Chih* (1880 edn), ch. 93, p. 6.
[344] *Tsai Yüan Tsa Chih*, ch. 4, p. 17; *Chhu Yü Kò Hua*, ch. 10, p. 1.
[345] *Ta Chhing Hui Tien*, ch. 1190, p. 3.

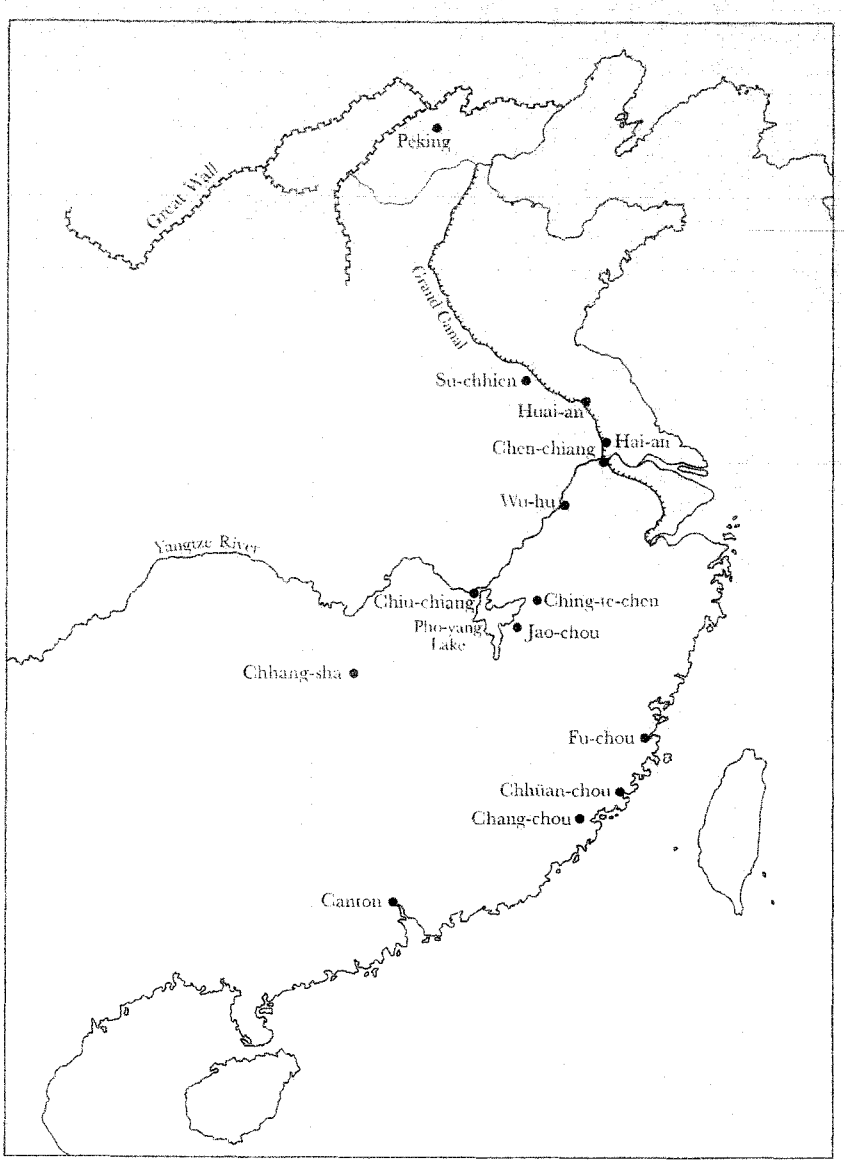


Fig. 42 Map of Ching-te-chen and its transport network by water, including Chiang-nan tax barriers on the Grand Canal

included jurisdiction over all Chiang-nan customs barriers. In +1728 Thang Ying 唐英 was appointed as his assistant, and while Nien mostly stayed at the customs house at Huai-an making spring and autumn factory inspections, Thang supervised work at the kilns. Thang dispatched finished products on the second and twenty-sixth of every month to Huai-an for Nien to inspect, before forwarding them to court.[346] When Nien was removed at the end of +1735 on corruption charges, Thang took over as Superintendent. He served altogether (with brief intervals) until +1756[347] (for more details of Thang Ying's achievements see Part 1).

A series of altar vessels commissioned by Thang Ying for temples at Peking bear long inscriptions that confirm the Superintendent's rank and responsibilities at that time.[348] With very slight variations, the inscriptions say:

Made by the Chief Superintendent of Works for the Yang-hsin Tien 養心殿.[349] Respectfully made by Thang Ying of Shen-yang 瀋陽, imperially appointed Superintendent of the Three Customs Barriers at Huai[-an], Su[-chhien] and Hai[-an] in Chiang-nan 江南淮宿海, and also Controller of Pottery in Chiangsi and of customs affairs at the customs house at Chiu-chiang, Junior Secretary of the Imperial Household and Captain of the Banner promoted five honorary ranks . . .

Thang Ying himself gained an assistant in +1741, called Lao Ko 老格, who was appointed on a three-year rolling contract.[350] Lao acted as right-hand man until Thang's retirement and subsequent death, and then took over a lot of responsibility. After Lao Ko's retirement in +1768, a decline in standards was evident.[351] The men who served as Superintendents during Thang Ying's absences from Ching-te-chen, and after his death, were not distinguished and only served for very short periods. They were:

Hui Se 惠色 (served +1750–2);
Yu Pa-Shih 尤拔世 (+1756–9);
Shu Shan 舒善 (+1759–62 and +1767–8, a corrupt official who stole samples see p. 208);[352]
Hai Fu 海福 (+1762–7);[353]
Thang Chhi 瑭琦 (one month in +1768);[354]
I Ling-A 伊齡阿 (+1768–72);[355]

[346] *Ching-te-chen Thao Lu*, ch. 5, p. 7a; Fu Chen-Lun & Chen Li (1982), pp. 21–2.
[347] Kerr (1986), pp. 19–20.
[348] Cf. Kerr (1986), pp. 19–20, 66–7, pl. 45, Sung Po-Yin (1995), cat. 75. Thang's manufacture of at least six sets of altar vessels for temples in and east of Peking is recorded as having taken place in +1734, +1740 and +1741, see Fu Chen-Lun & Chen Li (1982), pp. 32, 59; Peter Y. K. Lam (2000), pp. 74–5.
[349] The *Yang-hsin Tien Tsao-pan Chhu* 養心殿造辦處 ('Workshop in the Hall of Moral Cultivation') was an agency of the Imperial Household Department (*Nei-wu Fu* 內務府) staffed by eunuchs who produced things needed in the ordinary service of the emperor, see Hucker (1985), p. 576.
[350] Lao Ko was possibly surnamed Chao 趙, according to a reference for the seventh day of the tenth month of +1768 in *Kung Chung Tang Chhien-Lung Chhao Tsou Che*. Elsewhere he is referred to by the surname Tshui 催, see p. 646.
[351] Ts'ai Ho-pi (1992), pp. 8–9, 19.
[352] *Kung Chung Tang Chhien-Lung Chhao Tsou Che*, *Tshe* 31, p. 187.
[353] *Ibid.*, *Tshe* 30, p. 153.
[354] *Ibid.*, *Tshe* 31, pp. 493, 626, 674.
[355] *Ibid.*, *Tshe* 31, pp. 673; *Tshe* 33, p. 224.

Li Han 李瀚 (a temporary substitute in +1773–4);[356]
Chhüan Te 全德 (+1773–8);[357]
Su Ling-A 蘇凌阿 (+1778);[358]
Wan Chung-Chieh 萬鍾傑 and Mu Kho-Teng 穆克登 (exact dates unknown);
Chhien Li-Pao 虔禮寶 (? till +1786);
Hai Shao 海紹 (+1786–9);[359]
and Shan Thai 善泰 (+1789–?).[360]

Corruption during the second half of the +18th century resulted in changes to the management of the imperial factory. After +1787, superintendents (who managed kiln revenue and taxes) were no longer sent from the Imperial Household Department, but were recruited from local officials and the militia.[361] However, the court continued to influence the selection of officials[362] and to demand yearly quotas of official wares. By the mid +19th century Superintendents spent less time managing the imperial kiln, than chasing local bandits.

In fact, the Superintendents of the imperial factory were only really needed for springtime pre-manufacturing design decisions, and for autumn inspection of the annual quota of vessels for court.[363] It was the Superintendents' deputies who were really in charge, and who managed day-to-day production. Thus Thang Ying had deputised for Nien Hsi-Yao, and after Lao Ko's departure in +1768 a series of deputies were dispatched from Peking to learn the business. After +1777 two assistants were employed, but by the end of the +18th century the system had broken down.[364] In +1786 both deputies died, and kiln management was turned over entirely to local officials.[365]

Production Quotas

During the Ming dynasty official demands for porcelain frequently outstripped the capacity of the imperial factory. Private kilns made up the shortfall, culminating in the *Kuan-ta Min-shao* 官搭民燒 system described below. Already by +1402 there were twenty official kilns (in addition to the imperial factory) making wares for court,[366] and by the Hsüan-Te reign period this had increased to 58 'most of them outside the factory scattered among the popular kilns'.[367] Kilns in the imperial factory and private kilns making imperial ware used the same amount of wood, but the

[356] *Ibid.*, *Tshe* 33, p. 366; *Tshe* 34, pp. 608, 610.
[357] *Ibid.*, *Tshe* 35, p. 699.
[358] *Ibid.*, *Tshe* 43, p. 525.
[359] *Ibid.*, *Tshe* 60, p. 651; *Tshe* 73, p. 95.
[360] *Ibid.*, *Tshe* 73, p. 532.
[361] *Ibid.*, *Tshe* 43, pp. 525, 776. *Chiangsi Thung Chih* (1880 edn), ch. 94, p. 4a. Peter Y. K. Lam (2000), p. 79.
[362] *Kung Chung Tang Chhien-Lung Chhao Tzou Che*, *Tshe* 67, p. 847.
[363] *Ibid.*, *Tshe* 32, p. 635.
[364] *Ibid.*, *Tshe* 32, p. 638; *Tshe* 40, p. 670; *Tshe* 43, p. 775.
[365] *Ibid.*, *Tshe* 62, p. 422.
[366] *Chiangsi Sheng Ta Chih* (1597 edn), ch. 7, p. 3a; *Jao-chou Fu Chih* (1872 edn), ch. 3:3, p. 51. Feng Hsien-Ming *et al.* (1982), pp. 364–9.
[367] *Ching-te-chen Thao Lu*, ch. 5, p. 3a.

latter were less exacting and more productive, yielding twice the number of pots in any one firing.[368] Thus by +1436 the people of Fu-liang were able to send over 50,000 porcelain vessels to court and were rewarded with money.[369]

Huge consignments on this scale could not be kept up, and frequent petitions to reduce quotas were recorded. In the fifth year of the Ching-Thai reign period (+1454) annual production at Jao-chou was reduced by one-third.[370] In +1459 the Court of Imperial Entertainments (*Kuang-lu Ssu* 光祿寺) ordered over 133,000 porcelain vessels from Jao-chou. The Ministry of Works recognised the suffering and hardship facing the people and reduced the order by 80,000 items. This was one contest in which Confucian bureaucracy won out, for the emperor decided to accept the Ministry's decree.[371] At the beginning of the Chheng-Hua reign period from +1465 to +1468, production of porcelain was halted by imperial edict. After +1468 requests for porcelain from the Court of Imperial Entertainments were reduced by a quarter.[372] Later in the reign numbers of wares produced increased again. In +1476 10,000 vessels were made, 7,000 for the Court in Peking and 3,000 for Nanking.[373]

In +1502 the Court of Imperial Entertainments reduced its demand for as-yet unfinished pieces by one-third; but decreed that pieces already completed should be sent to court for distribution.[374] After the 18th year of Hung-Chih (+1505), apart from annual export quotas, porcelain manufacture at Jao-chou was temporarily suspended for three years (i.e. +1505–7).[375] This was because at the beginning of the Cheng-Te reign period, over 300,000 vessels ordered during the previous Hung-Chih reign period had still not been completed.[376]

In the second month of +1546, an order came from the official Sun Khuai 孫噲 of the Court of Imperial Entertainments to stop the year's production.[377] Work had already started and the potters could not be left idle all year. The result was simply to include two years' orders in one, so that the next year yielded an especially high number of pieces (see Table 33). Year-on-year production varied quite considerably, as demonstrated by Table 33, which shows production numbers for individual years of the Chia-Ching reign period. Archives recording production prior to that time were destroyed in +1529.[378]

During the Lung-Chhing reign period over 100,000 pieces of porcelain were made in Chiangsi province.[379] However, in the fifth year of the reign period (+1571)

[368] *Chiangsi Sheng Ta Chih*, ch. 7, p. 17a.
[369] *Chung-Kuo Li-Tai Shih-Huo-Chih Cheng-Pien* vol. 2, p. 942.
[370] *Ta Ming Hui Tien*, ch. 194, p. 4a/2632.
[371] *Ming Ying-Tsung Shih Lu*, ch. 309, p. 3b/6498.
[372] *Ta Ming Hui Tien*, ch. 194, p. 4a/2632. See Liu Hsin-Yuan (1993), pp. 28 and 68, who refers to *Ming Hsien-Tsung Shih Lu*.
[373] *Ta Ming Hui Tien*, ch. 201, p. 26b/2715.
[374] *Chung-Kuo Li-Tai Shih-Huo-Chih Cheng-Pien*, vol. 2, p. 942. *Ta Ming Hui Tien*, ch. 194, p. 4b/2632.
[375] *Ta Ming Hui Tien*, ch. 194, p. 4a/2632.
[376] *Chung-Kuo Li-Tai Shih-Huo-Chih Cheng-Pien*, vol. 2, p. 942.
[377] *Yü-chang Ta Shih Chi* quoted in *Jao-chou Fu Chih* (1872 edn), ch. 3.3, p. 62a.
[378] Numbers taken from *Chiangsi Sheng Ta Chih* (1597 edn), ch. 7, pp. 33a–44b. See also Feng Hsien-Ming *et al.* (1982), pp. 364–9.
[379] *Chung-Kuo Li-Tai Shih-Huo-Chih Cheng-Pien*, vol. 2, p. 942.

Table 33 *Numbers of porcelain items produced at the imperial kiln during the Chia-ching reign (+1522–66)*

Reign	Year	No. of items
Chia-Ching 8	+1529	2,570
Chia-Ching 10	+1531	12,300
Chia-Ching 13	+1534	6,160
Chia-Ching 16	+1537	948
Chia-Ching 17	+1538	1,510
Chia-Ching 20	+1541	27,300
Chia-Ching 21	+1542	2,830
Chia-Ching 22	+1543	16,410
Chia-Ching 23	+1544	70,950
Chia-Ching 24	+1545	1,920
Chia-Ching 26	+1547	120,260
Chia-Ching 27	+1548	9,200
Chia-Ching 29	+1550	1,000
Chia-Ching 30	+1551	10,830
Chia-Ching 31	+1552	44,750
Chia-Ching 33	+1554	100,030
Chia-Ching 34	+1555	1,470
Chia-Ching 35	+1556	34,891
Chia-Ching 36	+1557	31,580
Chia-Ching 38	+1559	29,260

there was a shortfall and so officials Hsü Shih-Shu 徐拭疏 and Tshui Min 崔敏 demanded extra manufacture of certain quantities. Some 105,770 vessels were ordered, comprising bowls, jars, cups, vases, boxes with red interiors, and both large and small dragon cisterns.[380] In spite of a new initiative at the factory in +1572, when the Assistant Prefect of Nan-khang 南康, Chhen Hsüeh-Chhien 陳學乾, was appointed Supervisor,[381] this order was not completed within the reign. This was a time of famine and hardship in Chiangsi province, when many potters stopped work and switched to other professions.[382]

In +1591 159,000 porcelain vessels were ordered, and an additional order of 80,000 was added; but the kilns were not able to complete them for many years.[383] In +1607 an official from the Ministry of Works inspected the dispatch of the first 159,000 items, while the remaining 80,000 were divided into eight shipments. After the seventh shipment officials gave up, leaving behind some 10,000 pieces.[384] This

[380] *Chiangsi Sheng Ta Chih* (1597 edn), ch. 7, p. 45b. *Jao-chou Fu Chih* (1872 edn), ch. 3.3, p. 59a, here quoting *Fu-liang Hsien Chih*.
[381] *Chiangsi Sheng Ta Chih* (1597 edn), ch. 7, p. 10b. *Jao-chou Fu Chih* (1872 edn), ch. 3.3, p. 55b.
[382] *Chiangsi Sheng Ta Chih* (1597 edn), ch. 7, p. 45b.
[383] *Chung-Kuo Li-Tai Shih-Huo-Chih Cheng-Pien*, vol. 2, p. 942.
[384] *Ming Shen-Tsung Shih Lu*, ch. 434, pp. 10a–b/8217–18.

was in spite of the fact that an enormous amount of casual labour had been conscripted to fulfil orders. By +1606 it was said that over 10,000 daily workers were needed,[385] overburdening the system with semi-skilled labour.

It is apparent that the +16th century was a problematic period, and it was at that time that the *Kuan-ta Min-shao* system was instituted. Translating as 'official partnership with private kilns', it was a means of broadening the base of procurement of porcelain for the court. Everyday wares for the imperial household could be fired at private kilns, while special orders, including tribute gifts, could only be fired in the imperial factory.[386] Initially, few firms had enough skill to participate; during the Wan-Li reign period, for example, about twenty qualified. The system was problematic for private firms, who were financially penalised if they failed to produce satisfactory wares. It was supposed to guarantee quality, but actually served as a form of indirect taxation. If any of the private kilns failed to make porcelain of required quality, they had to buy comparable pieces at their own expense from the imperial factory.[387] Otherwise officials would buy replacement pieces and charge the private kilns exorbitant prices, fixed between local dealers, and the government itself![388]

In +1682 *Kuan-ta Min-shao* was revived.[389] During the Chhing dynasty the system functioned more effectively. At that period the imperial factory was hard-pressed to fulfil court orders, and some officials were grateful for assistance. In +1743 Supervisor Thang Ying gave thanks that there were no less than 200 to 300 areas of private kilns employing 100,000 craftsmen in the Ching-te-chen area.[390] Many private businesses were situated very nearby, in a cul-de-sac called Dragon Urn Lane 龍缸衚 just east of the imperial depot. Lucrative *Kuan-ta Min-shao* contracts were eagerly sought after in the heyday of the scheme from the +1680s to the +1740s. After +1743 private kilns expanded and increased in skill to the point where they became competitors with centrally organised official production.[391] This was one of many factors that led to a series of economies at the imperial factory throughout the second half of the +18th century. By the late +19th century the factory had declined to the extent that no high-temperature kilns were in operation at all, for all such firings were carried out at private firms. Only low-temperature muffle furnaces were still at work there.[392]

During the Chhing dynasty when official production was put out to private kilns, some found its way on to the market illegally, and widescale faking of imperial wares occurred.[393] Much more was legally consigned as rejects, however, and sent

[385] *Ibid.*, ch. 419, p. 2b. *Chiangsi Thung Chih* (1880 edn), ch. 49, p. 12a.
[386] *Fu-liang Hsien Chih* (1682 edn), ch. 4, p. 46b.
[387] Yuan Tsing (1978), pp. 47–8.
[388] *Fu-liang Hsien Chih* (1682 edn), ch. 4, pp. 46a–b.
[389] *Ibid.*, ch. 3, p. 62b.
[390] Fu Chen-Lun & Chen Li (1982), pp. 40, 61.
[391] Liang Miao-Thai (1991), pp. 146–7.
[392] Scherzer (1882), quoted in Tichane (1983), p. 189.
[393] Liang Miao-Thai (1991), p. 138.

to Peking for public consumption along with consignments of imperial ware.[394] Thus in the sixth month of +1742, Thang Ying recorded that he had received imperial permission to sell low-quality porcelains that could not be sent to court.[395] They were sold to dealers at 70% of the full price, a rate that Thang believed the dealers could well afford.[396] There was trouble if less-than-perfect wares exceeded quotas, and Thang Ying was reprimanded several times for this during his tenure. On one occasion in +1741 he was even ordered to pay compensation for poor-quality products and breakages.[397] This was because kiln wasters constituted about 20% of output and substandard products 50%, though statutes ruled that complete kiln wasters should not exceed 20% and substandard pieces 30%. Later on, standards declined yet further. Between +1870 and +1908 best-quality pieces only averaged about 25%, substandard wares 57% and wasters 18%.[398]

Porcelain Decorations and Sumptuary Regulations

We know from archaeology that small local kilns were operating in the hills to the north of Ching-te-chen by the +10th century.[399] Their original purpose seems to have been to copy the vastly popular Yüeh-type wares from neighbouring coastal Chekiang province, which had a grey body under their green glaze. Alongside these celadons, plain white porcelains were made. By the Sung dynasty reduction-fired glazes, faintly touched with blue, were the norm. This naturally beautiful product (called *chhing-pai* 青白, see discussion of the term on pp. 556–7) soon made Ching-te-chen famous, while celadon grew less popular. *Thao Chi* (Ceramic memoir, +13th C.) tells us that yellow and black wares from Hu-thien 湖田[400] were much liked by people in Chekiang province, while *chhing-pai* ware was enjoyed by customers in Chiangsi, Hunan, Szechuan and Kuangtung provinces.[401] The period from the late Northern Sung to the early Southern Sung dynasties (*c.* +1075–1150) was the high-point of production of *chhing-pai* porcelain.[402]

In the Yuan dynasty there was an explosion of new decorations and styles in imperial porcelain, many of them highly innovative. They included underglaze-blue decorated wares with five-clawed dragon designs, gilded wares and turquoise-glazed ware.[403] Such designs were possibly developed by court painters in the palace

[394] *Ching-te-chen Thao Lu*, ch. 2, pp. 1b–2a.
[395] Fu Chen-Lun & Chen Li (1982), pp. 35, 60.
[396] Liang Miao-Thai (1991), p. 137.
[397] Fu Chen-Lun & Chen Li (1982), pp. 27–43, 61–2; Peter Y. K. Lam (2000), p. 76.
[398] Liang Miao-Thai (1991), p. 136.
[399] For descriptions of Ching-te-chen's geography see Bushell (1896), pp. 148–50; Dillon (1976), pp. 15–17; Liang Miao-Thai (1991), pp. 239–59.
[400] One of the main kiln areas, four kilometres south-east of the city. The kiln is located on the edge of a playground of a modern junior school.
[401] Pai Khun (1981), p. 39.
[402] Chen Baiquan (1993), p. 23.
[403] Liu Hsin-Yüan (1993), pp. 33–6.

in the Painting Academy (*Hua Yüan* 畫院) that was under the jurisdiction of the Imperial Manufactories Commission.[404] Sumptuary regulations were already in force with regard to the decoration of porcelain, in particular the use of gold for gilding. In 1271 gold was prohibited for use on popular ware decoration or inscriptions. Five-clawed dragon and phoenix designs were another target for prohibition.[405] The use of gilding on Yuan dynasty ceramics is described further in Part 6, p. 704.

Not everyone regarded the new styles with favour. Writing in the early Ming dynasty Tshao Chao admired older, conservative, monochrome styles while decrying new, decorated wares:[406]

> The best imperial wares have a fine, lustrous body. Plain pieces with constricted waists and unglazed rims are also fine, for though they are thick they are white and smooth . . . Yuan dynasty wares with small feet, moulded designs and the mark *shu-fu* 樞府 are of very high ranking.[407] In contrast new pieces have large feet, the plain pieces lack unctuousness and the blue-and-white and polychrome wares are vulgar in taste.

In similar vein, the Yung-Le emperor, reacting to jade bowls brought in by foreign tribute in +1406, declared: 'It is deeply satisfying to one's spirits that the court should utilise familiar, bright, clean and unadorned Chinese porcelain vessels.'[408]

In the Ming dynasty, official ceramics were ordered for both ritual and everyday use. The first emperor Hung-Wu came from peasant stock, and his frugal good sense dictated that porcelain rather than bronze should serve for ritual, and that similar vessels be utilised for both ceremony and living.[409] In +1369 he issued an official decree on the matter of porcelain ritual vessels.[410] From +1368 sumptuary restrictions were enacted to cover imperial wares. For example, commoners were forbidden to use vessels decorated with dragon and phoenix designs, or with gilding.[411] In +1384 it was promulgated that all imperial ceramics must follow specific designs and that material and labour costs must be strictly controlled.[412] The proscriptions were repeated in the 26th year with even greater severity, when it was stipulated that wooden utensils also were forbidden to bear red or gold decoration, or painted or carved dragons and phoenixes.[413] It can be seen that specific decorations and forms denoted imperial status, and were reserved for palace use. Those designs

[404] Liu Hsin-Yüan (1982b), p. 16; Hucker (1985), pp. 140, 260. However, Shih Ching-fei (2001), pp. 97–8, argues that direct links between the Painting Academy and the Porcelain Bureau cannot be established.

[405] *Ta Yüan Sheng Cheng Kuo Chhao Tien Chang*, ch. 58, pp. 12–13/790–1.

[406] *Ko Kü Yao Lun*, ch. 3, pp. 40a–b. David (1971), pp. 142–3, 305.

[407] *Shu-fu* was a style of *chhing-pai* ware made in the Yuan dynasty, with a thicker body and an opaque, milky, blue-white glaze. The characters *shu-fu* mean 'Privy Council' and are believed to have been made for the Bureau of Military Affairs *Shu-mi Yüan* 樞密院. Hucker (1985), p. 436; Scott (1992), p. 46. In spite of the fact that *shu-fu* porcelains should have been official wares, many were exported throughout South-east Asia and beyond.

[408] *Ming Thai-Tsu Shih Lu*, ch. 60, p. 8.

[409] *Ming Thai-Tsu Shih Lu*, ch. 29, p. 4. In +1368 Hung-Wu was already employing porcelain *chüeh* 爵 vessels. *Ming Thai-Tsu Shih Lu*, ch. 31, p. 5.

[410] *Ming Thai-Tsu Shih Lu*, ch. 44, p. 8.

[411] *Huang Ming Chih Shu*, ch. 1 ('*Ta Ming Ling*'), p. 21.

[412] *Ta Ming Hui Tien*, ch. 194, p. 1a/2631.

[413] *Ming Shih, Chih* 44, ch. 58, p. 714.

gave added value to the porcelains, and frequent prohibitions suggest how often rules were transgressed. In the third year of Cheng-Thung (+1438), a palace decree again forbade the manufacture, sale or distribution of imperial-style blue-and-white porcelain to officials' families. Private kilns were also forbidden to make yellow, purple, red, celadon and blue wares. The punishment for offence was death, confiscation of all possessions, and military conscription for all male members of the clan to the border regions.[414]

Different patterns were ordered for different departments of the imperial household; for example, all yellow and green wares with paired dragon and phoenix designs were for the Directorate for Palace Delicacies (*Shang-shan Chien* 尚膳監),[415] while plain whitewares with dragon and phoenix decoration were for the Court of Imperial Entertainments.[416] Many individual orders for specific purposes were recorded. Thus at the beginning of the Hsüan-Te reign period official supervision was supplied for the making of white porcelain vessels with dragon and phoenix designs for palace banquets.[417] In the ninth month of +1427 the Ministry of Works ordered white ritual porcelain vessels to be made for palace ceremonies.[418] In +1433 an official was sent down from the Ministry of Works to supervise production of 443,500 vessels decorated with dragon and phoenix and other designs that had been ordered.[419] In +1441 white porcelain jars with gold dragon and phoenix designs were ordered for the Court of Imperial Entertainments.[420] In addition, white porcelain cisterns decorated with blue dragons were ordered to stand in front of three newly built halls in the palace. Those made under the supervision of eunuch Wang Chen 王振 had cracks. An imperial eunuch was sent to supervise the remaking of the cracked vessels, and he was rewarded with silk robes and batons.[421] Not one of the dragon cisterns reached Peking. Kiln wasters from 27 failed cisterns were broken up and buried under the west wall of the imperial kiln area, from whence they were excavated in the +1980s (see Fig. 43).[422]

During the Chia-Ching reign period many orders for special, ceremonial ceramics were recorded. In +1528 Jao-chou was detailed to produce an additional 189 lead-lined ice-chests for the autumn offering at the Civil Temple (*Wen Miao* 文廟).[423] In +1530 porcelain vessels for the various imperial monuments in the four suburbs of Peking were ordered: celadon blue (*chhing* 青) for the Temple of Heaven; yellow for the Temple of the Earth; red for the Temple of the Sun; and white for the Temple

[414] *Ming Ying-Tsung Shih Lu*, ch. 49, p. 4b/0946; ch. 161, p. 4b/3132.

[415] One of twelve major directorates, headed by a eunuch Director, responsible for providing special foods from the palace gardens, see Hucker (1985), p. 410.

[416] *Ta Ming Hui Tien*, ch. 194, p. 3a/2632.

[417] *Chung-Kuo Li-Tai Shih-Huo-Chih Cheng-Pien*, vol. 2, p. 942.

[418] *Ming Hsüan-Tsung Shih Lu*, ch. 9, p. 4a/0231.

[419] *Ta Ming Hui Tien*, ch. 194, p. 3b/2632.

[420] *Ming Ying-Tsung Shih Lu*, ch. 79, pp. 2a–b/1557–8. A comparative entry in *Ming Shih* says that after the completion of palace building, porcelain food vessels decorated with nine dragons and nine phoenixes were ordered.

[421] *Chung-Kuo Li-Tai Shih-Huo-Chih Cheng-Pien*, vol. 2, p. 942.

[422] Liu Hsin-Yüan (1993), pp. 40–1.

[423] *Ta Ming Hui Tien*, ch. 201, p. 26a/2715.



Fig. 43 Large repaired cistern excavated from the Cheng-Thung period strata

of the Moon.[424] In +1537 new ritual vessels for seven imperial tombs were requisitioned;[425] in +1538 Jao-chou dispatched 1,510 completed pieces of white porcelain, including plates and *chüeh* 爵 and 150 spare items, for the Yung-Le emperor's tomb (*Chhang Ling* 長陵).[426] In +1555 the Assistant Prefect of Chiangsi province (who was then also Supervisor of the imperial factory) was questioned about the poor quality of porcelain coming from the kilns. For this reason, in +1558 an official from the court was sent to Chiangsi to supervise the making of 30,000 porcelain vessels for religious temples in the palaces.[427]

As the +16th century progressed, special orders increased and management became harsher. In the 12th year of Wan-Li (+1584) the Ministry of Works reported the difficulties of porcelain-making, especially of unusual and delicate pieces. So the manufacture of chess boards and screens was reduced by one-half.[428] In +1585, palace official Shu Chih-Ko 疏至閣 directed the continued production of porcelain screens, candle stands, chess boards and flower vases that had already commenced,

[424] *Ta Ming Hui Tien*, ch. 201, p. 25b/2715. See also Christine Lau (1993), pp. 94–6. Vessels for the Peking temples continued to be made during the Ming and Chhing dynasties. In the first month of the 15th year of the Chhien-Lung reign period (+1750), the imperial kilns sent over 150 ritual vessels for the Altars of Heaven and Earth, see Fu Chen-Lun & Chen Li (1982), pp. 50–64.

[425] *Chung-Kuo Li-Tai Shih-Huo-Chih Cheng-Pien*, vol. 2, p. 942.

[426] *Ta Ming Hui Tien*, ch. 201, p. 26a/2715.

[427] *Chung-Kuo Li-Tai Shih-Huo-Chih Cheng-Pien*, vol. 2, p. 942.

[428] *Chiangsi Sheng Ta Chih* (1597 edn), ch. 7, p. 48a, *Ming Shen-Tsung Shih Lu*, ch. 147, p. 6b/2746.

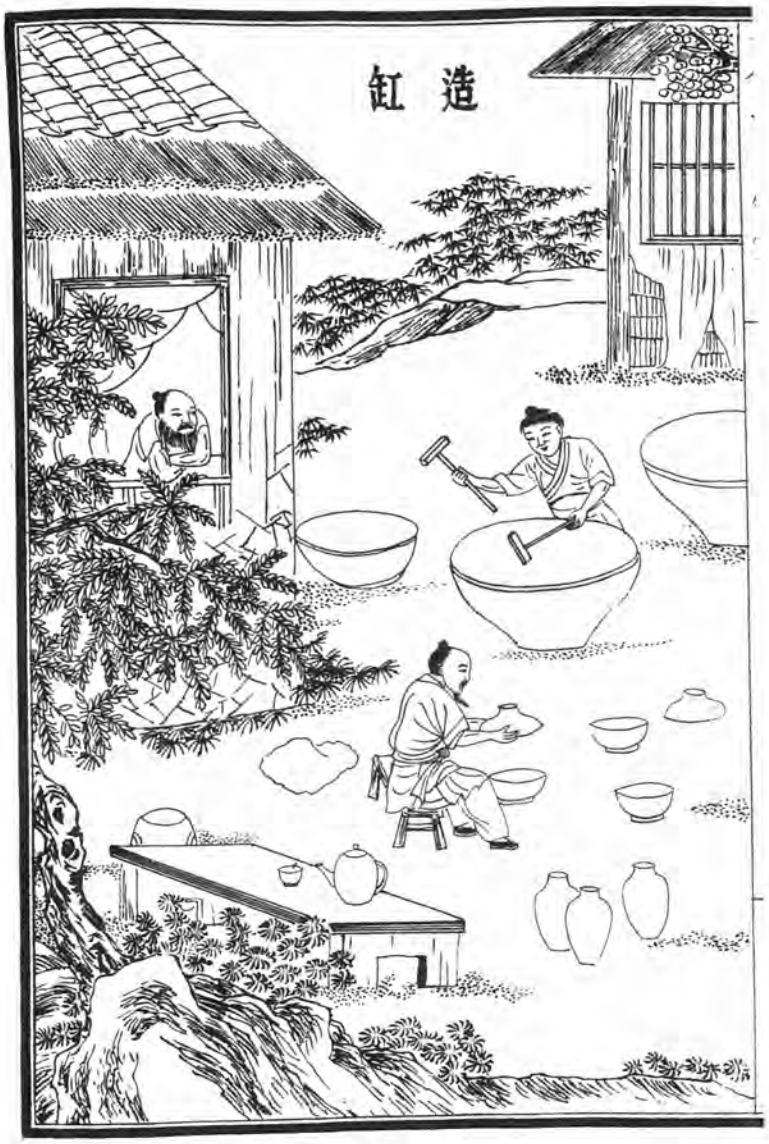


Fig. 44 Making large cisterns. From *Thien Kung Khai Wu* (+1637)

but that those not yet begun should be cancelled. It was said that fashionable, large, dragon cisterns were very hard to make, and they were also stopped.[429]

Some large cisterns took so much sweat and toil to produce, that samples were dedicated to the temple of the God of Kilns at the factory. In the fifth month of +1730, Thang Ying (Supervisor of the imperial factory) had removed a huge, green,

[429] *Chiangsi Sheng Ta Chih* (1597 edn), ch. 7, p. 48a. *Ming Shen-Tsung Shih Lu*, ch. 147, p. 6b.

Wan-Li dragon cistern that had been extremely difficult to make, from an older temple into what was then called 'The Temple of the Potter's Guardian Spirit' (*Yu-thao-ling Ssu* 佑陶靈寺).[430] The deity was described by Thang in his 20th description of illustrations of ceramic manufacture (*Thao Yeh Thu Pien Tzhu*, +1743, see Part 1).[431] Thang said the god was surnamed Tung 董, and that he had once been a potter, who in the Wan-Li reign period of the Ming dynasty had sacrificed his life for his fellows. Large dragon cisterns had failed in the kiln repeatedly and eunuch officials had exacted cruel punishments. Tung hurled himself into the kiln and afterwards the dragon cisterns fired perfectly. His fellow workers built a temple to him within the walls of the imperial factory, dedicated to the 'Immortal of the Flaming Kiln' (*Feng-huo hsien* 風火仙), at which they worshipped annually.[432]

This touching tale probably says more about Thang's own anxieties about failure, than about the true origins of worship of a pottery deity. A much earlier reference to such a figure occurred in the strange tales of Kan Pao 干寶, written in the mid +4th century. Kan related how the Controller of Pottery (*Thao-cheng* 陶正) under the legendary Yellow Emperor, burnt himself to death in a kiln leaving his bones intact, which were buried with reverence in the Ning mountains 甯山.[433] And at the very beginning of the Ming dynasty, the Hung-Wu emperor was already sanctioning offerings to the God of Pottery of ancient times, who continued to protect skilled potters in their difficult craft.[434] We also describe several Sung dynasty monuments that revered pottery deities in the Yao-chou kiln area, and customs at other kilns such as Te-hua (see pp. 166–7, 243–4 and 566–7).

During the Chhing period lists of requirements from the Palace Workshops (*Tsao-pan Chhu* 造辦處) continued to be sent to Ching-te-chen. At the beginning of the dynasty things got off to an unsuccessful start, when attempts to fulfil imperial orders failed in +1654 and +1659. In +1660 provincial Governor Chang Chhao-Lin 張朝璘 petitioned for permission to stop the work.[435] After the re-establishment of the imperial factory in +1680–3 production became more regular, and in +1689 porcelain warehouses were reinstated by the Storage Office (*Kuang-chhu Ssu* 廣儲司) to store items selected for court in readiness for their journey north.[436] Thang Ying noted that every autumn and winter after +1728, consignments of nearly 20,000 items were sent to Peking.[437]

Lists for several years of the Chhing dynasty were recorded. Those for the autumn 8th month of +1724 and for +1864 have been translated into English, and

[430] He wrote an inscription for the temple and an account of the exploit in his book *Thao Jen Hsin Yü*, ch. 6, see Fu Chen-Lun & Chen Li (1982), pp. 22–3, 56.

[431] *Thao Shuo*, ch. 1, pp. 12a–b. Bushell (1910), pp. 28–9.

[432] *Fu-liang Hsien Chih* (1682 edn), ch. 7, additional notes. *Chiangsi Thung Chih* (1880 edn), ch. 93, pp. 9b–10a. Bushell (1910), pp. 28–9.

[433] *Sou Shen Chi*, ch. 1, p. 2. Cf. DeWoskin & Crump (1996), p. 2.

[434] *Ming Thai-Tzu Yü Chih Wen Chi*, ch. 20, pp. 575–6.

[435] *Ching-te-chen Thao Lu*, ch. 2, p. 1a.

[436] *Ta Chhing Hui Tien*, ch. 1190, p. 3. The *Kuang-chhu Ssu* was one of seven major units in the Imperial Household Department that managed storehouses in the palace, cf. Hucker (1985), p. 287.

[437] Feng Hsien-Ming *et al.* (1982), p. 416.



Fig. 45 Page from 'Illustrated Regulations for Ceremonial Paraphernalia of the Chhing Dynasty' showing yellow-glazed ceramic vessel in bronze form *tou*, for the Temple of the Earth

can thus readily be consulted.[438] They throw an interesting light on changing requirements. In the Yung-Cheng reign period, demand was for copies of wares of past dynasties, such as Sung dynasty *chhing-pai*, Ko, Ju, Ting, Chün and Lung-Chhüan, and Ming dynasty Yung-Le, Hsüan-Te, Chheng-Hua, Chia-Ching and Wan-Li porcelain. In the +19th century taste had shifted to brightly decorated and coloured wares.

Designs for imperial porcelains sent to Ching-te-chen included flat surface patterns for decoration, 3-D wooden forms, wax models or actual pieces from the imperial collection. Some porcelain designers worked in the Imperial Household Department (*Nei-wu Fu* 內務府) while others were court painting craftsmen. Samples were made, inspected and approved, and were then put into mass-production. Very special enamelled items required specially skilled workers, and in these cases enamel painters joined large painting commissions at court or in the *Ju-i Kuan* 如意舘

[438] Bushell (1896), pp. 194–205, 242–7; Kuan Shan-Ming (1983), pp. 6–7, 22–3. The lists were taken from *Chiangsi Thung Chih* (1880 edn), ch. 93, pp. 10b–16a.



Fig. 46 Porcelain vessels with blue glaze in bronze form *tou* 豆 and bronze form *fu* 簠, for the Temple of Heaven

(Institute of Indulgences, see also pp. 641–2).[439] Towards the end of the +18th century control of design work waned. In +1768 it was reported that Kiln Superintendent Shu Shan 舒善 had misappropriated porcelain samples from Ching-te-chen. Out of an original total of 8,400 only 4,568 remained. Samples were supposed to be kept in the imperial factory even if imperfect, in case they were needed again.[440] This was one of the reasons that many +19th-century imperial porcelains bore the same forms and patterns as those of the +18th century. When Ching-te-chen was razed in +1855 during the Thai-phing Rebellion most of the porcelain models were destroyed.[441]

Sumptuary regulations continued to be re-enacted, to protect special types of ceramics ordered for the imperial household. Ceremonial wares were strictly systematised, their details set down in the *Huang Chhao Li Chhi Thu Shih* (Illustrated Regulations for Ceremonial Paraphernalia of the Chhing Dynasty, +1759).[442]

As well as offering vessels, everyday wares for the palace were also regulated, with colours and designs for each member of the imperial family listed as to rank.[443]

[439] Yang Po-Ta (1993), pp. 41–2. The *Ju-i Kuan* was established in the Chhien-Lung reign period as a centre within the palace where court painters worked, Hucker (1985), p. 273.

[440] *Kung Chung Tang Chhien-Lung Chhao Tsou Che, Tshe* 31, p. 49; *Tshe* 32, p. 35.

[441] *Nei-Wu Fu Tsou Hsiao Tang* for the 3rd year, 8th month, 26th day of Thung-Chih.

[442] *Huang Chhao Li Chhi Thu Shih* in eighteen chapters, completed in +1759 and revised in +1766. See Medley (1960), and Kuan Shan-Ming (1983), pp. 8–9, 26–7.

[443] *Kuo Chhao Kung Shih*, ch. 17–18, pp. 613–746. Cf. Kuan Shan-Ming (1983), pp. 9–10, 27–8.

Frugal emperors could demonstrate their parsimony by prohibiting expensive designs. Thus the Tao-Kuang ruler ordered cessation of production of the more elaborate creations of the Chhien-Lung reign period.[444]

Labour Relations

When an imperial bureau was founded in the Yuan dynasty, items for court were made by workers conscripted into compulsory labour. From the beginning of the Ming dynasty, there were two sorts of workers at the imperial factory. The first category was relatively unskilled labour that was drafted in from the seven counties of Jao-chou prefecture in rotating crews (lun-pan) 輪班, and crowded into temporary accommodation in the city. The second category was skilled artisans who devoted a proportion of their labour as corvée in the imperial factory, but could work for themselves when not on duty. They worked a shift system, some devoting ten days each month, and others working three months a year over a three-year contract. In theory, these workers only served a single term of labour in the imperial factory, and could pay money to be absolved from that term. In practice, demands from court meant that the factory was often behind schedule, and that skilled workers were repeatedly on call.[445] By the Hsüan-Te reign period, 590 workers were conscripted at the imperial factory in rotating crews, along with 367 artisans; altogether about 1,000 men worked for four-month periods.[446]

In parallel with production of official wares, manufacture at a host of privately managed kilns in and around the city flourished. *Chiangsi Sheng Ta Chih* (Great Gazetteer of Chiangsi Province, +1597) spelt out the differences between work at the imperial kiln and that at privately-owned ones: 'Private and official businesses are different. Officials work for pleasure and duty, while private workers labour hard to protect their livelihood.'[447]

From +1507 until about +1590, China's economic growth accelerated, particularly in the south-east of the country, and the porcelain industry expanded at high speed.[448] During the flourishing Chia-Ching reign period no fewer than 10,000 people in greater Ching-te-chen were involved in ceramic production.[449] Corvée labour at the imperial factory was registered at several hundred. Following the single whip tax reforms of +1560, corvée was supplemented and then gradually replaced by waged labour, but the second half of the Ming dynasty also saw deteriorating control and worsening conditions for the labour force. From the mid +16th century onwards until the end of the Ming dynasty, memorials to court multiplied. Early in the Chia-Ching reign period, a eunuch was sent to be Superintendent and this man

[444] *Chiangsi Thung Chih* (1880 edn), ch. 1, p. 3b.
[445] Feng Hsien-Ming *et al.* (1982), pp. 357, 361–2. For further details of how the corvée system operated, see Ray Huang (1974), pp. 32–8.
[446] Anon. (1959a), pp. 103–4.
[447] *Chiangsi Sheng Ta Chih*, ch. 7, p. 17b.
[448] Ray Huang (1969), p. 110.
[449] *Ming Shih-Tsung Shih Lu* (*Chia Ching*), ch. 240, p. 5.

Chhen Kao-Mo 陳皐謨 reported great suffering among the people and pleaded for production to stop. The emperor did not listen.[450] In +1586 an official from Chiangsi, Chhen Yu-Nien 陳有年, petitioned to reduce the production of new-fangled wares but to continue supplying essential ritual vessels. In +1587 Chhen again petitioned to stop the manufacture of exceptionally difficult types of porcelain, such as chess boards and jars, screens, brushpots, boxes, large vases and incense burners. In the second month of +1594, officers from the Ministry of Works petitioned the reduction of porcelain production to mitigate the great hardships being suffered by the inhabitants of Chiangsi, but their request was refused.[451]

Famine exacerbated trouble, often leading to bloody fights between mobs from different districts. One example was incidents recorded in the summer of +1541. Spring floods that year had inundated kilns and caused many kiln owners to lay off workers. Unemployed potters from the county of Le-phing 樂平 outside Ching-te-chen city accused the city's shopkeepers of plotting to sell food only to local families. Riots ensued, which a skeleton militia could do nothing to control, and there were a great number of deaths.[452] The official verdict saw the conflict in these terms:[453]

> Men from Le-phing county in Chiangsi are drafted to work in Fu-liang. In years of food shortages men in Fu-liang, who bear the larger share of costs, neglect them or drive them out. The Le-phing men then sack property and rob people. Criminals from both counties gather in gangs of over 1,000 men, brawling and killing one another.

In fact, there had been previous violent conflict between Fu-liang and Le-phing gangs in +1537 and +1540. By +1563 matters had become so grave that the assistant prefect of Jao-chou, Fang Shu-Yu 方秫猷, suggested that the city be given powers to administer the affairs of ten local counties from whence came pottery workers.[454] Police stations were established every mile (*li* 里) within a thirteen-mile radius, to control problems caused by robbery and to monitor the movements of residents. The assistant prefect was to take on powers of surveillance and crime prevention, in addition to his (then) duties as Superintendent of the imperial factory.[455]

After the devastation that accompanied the Ming–Chhing transition, potters slowly trickled back into Ching-te-chen and officials tried to resurrect production. After Khang-Hsi's intervention of +1680, corvée was replaced with waged labour[456] and a core of skilled workers was conscripted into the imperial factory, becoming permanent residents there. Others were drafted in from outlying counties, as needed, for the previous large population of city dwellers had dispersed following the sacking of the town during the civil war of the early +1670s. Local gazetteers

[450] *Chung-kuo Li-Tai Shih-Hao-Chih Cheng-Pien*, vol. 2, p. 942.
[451] *Chiangsi Sheng Ta Chih* (1597 edn), ch. 7, p. 50a. *Ming Shen-Tsung Shih Lu*, ch. 270, p. 3a/5013.
[452] *Fu-liang Hsien Chih* (1682 edn), ch. 8, p. 27b. *Chiangsi Thung Chih* (1880 edn), ch. 96, p. 33b.
[453] *Ming Shih Lu*, quoted in Anon. (1959a), p. 239.
[454] These were Li-jen 里仁, Chhang-hsiang 倡香, Pho-yang 鄱陽, Yü-kan 餘干, Te-hsing 德興, Le-phing 樂平, An-jen 安仁, Wan-nien 萬年, Nan-chhang 南昌 and Tu-chhang 都昌.
[455] *Jao-chou Fu Chih* (1872 edn), ch. 3.3, p. 56a, here quoting from *Fu-liang Hsien Chih*.
[456] *Ching-te-chen Thao Lu*, ch. 2, p. 11a.

recorded that since the uprisings in which workshops and dwellings had been razed, only two or three out of every ten porcelain workers remained in the city. Shops and houses had all been sold to incomers from other areas.[457]

The city of Ching-te-chen spread southwards during the Ming and Chhing dynasties, for it was hemmed in to the north and west by high ground. In the Ming, most private kilns were built on a perimeter of hills extending around the Chu-shan area. Many kilns and houses were located on Pan-pien Chieh (One-sided Street 半邊街) near the docks and the narrow lanes intersecting Cheng Chieh (Main Street 正街) whose names evoked the pottery business: Huo-shao Thung (Firing Lane 火燒衕), Thieh-chiang Thung (Blacksmiths' Lane 鐵匠衕), Lung-kang Thung (Dragon Urn Lane 龍缸衕). After +1682 there was enormous demographic growth at Ching-te-chen, and work and living spaces encroached into the flood-prone, low-lying fields to the south. Wealthy speculators gradually bought up the small houses and shops in the centre of the city, sure of certain profits. The Governor of Chiangsi province lamented in +1730: 'Most merchants rent out dwellings in the pursuit of their despicable profession. They invariably throw out the old and the sick who are unable to work.'[458] The narrow, congested streets posed great risk of fire. An early +16th-century source recorded big fires in +1429, +1473, +1476, +1493 and +1494,[459] and many more were to follow. The Jesuit Père d'Entrecolles wrote from Jao-chou in +1712:[460]

> The streets are set out in straight lines, which bisect one another at set distances. But all the space there is occupied, the houses are densely packed and the streets are too narrow . . . At present there are 3,000 porcelain furnaces. It is not surprising that one sees frequent conflagrations . . . Only a short time ago there was a fire that burned 800 homes down.

At its peak of prosperity in the mid Chhing dynasty the city had several hundred large kilns and a mass of smaller muffle furnaces. Packed into the city streets, these businesses greatly increased the incidence of fires.

Ching-te-chen was a rowdy city, prone to disorder. This is not surprising given the vast amount of wealth generated but kept in the hands of a few, the large population, the overcrowded living conditions and the presence of groups of conscripted workers living away from their families. There are many descriptions of the wretched lives of the inhabitants, especially by Western visitors to the city. Père d'Entrecolles wrote in +1712 how Ching-te-chen supported masses of poor families who could not subsist in other cities, as well as the young, the weak, the blind and the crippled.[461] As late as +1923, American journalist Harry Franck described the city:[462]

[457] *Fu-liang Hsien Chih* (1682 edn), ch. 9, p. 7a. *Chiangsi Thung Chih* (1880 edn), ch. 97, p. 9a.
[458] *Chiangsi Thung Chih* (1880 edn), ch. 94, p. 19b.
[459] *Chiangsi Thung Chih* (1525 edn), p. 9/1354.
[460] Tichane (1983), pp. 56–7, translation of Père d'Entrecolles letter of +1712.
[461] *Ibid.*, p. 57.
[462] Franck (1925), quoted in Tichane (1983), p. 371.

As utterly crapulous as any I had seen in China; no one, nothing, could really be called clean. The stench of human excrement, of never-washed people living in sty-like dens, the mangy scalps and ulcerated skins . . . were everywhere . . . They lived in hot dens succeeding one another endlessly along the narrow streets.

Porcelain production was always seasonal, because of the weather. In the +18th century, Thang Ying made complaint in his writings of the difficulties of trying to fulfil orders in the winter months, when the workshops were unheated and the clay froze (see p. 646). In general, the manufacturing season was from April to November, the height of summer being the busiest time of year. However, Thang Ying considered the most important seasons were spring and autumn. Design decisions were taken in the second/third months while colours and glazes were prepared, and firing was most successful in the eighth/ninth months when it was dry and windy.[463]

Both workers within factories and those in ancillary trades had their own labour organisations. Porcelain production was already governed by guild regulations by the early Ming dynasty, though the development of the system is not properly documented. The purpose of guilds was to set and maintain standards, to organise demarcation between trades and to provide various social, ritual and religious functions.[464] Long after workers had arrived in the city, the dominances of kinship and locality continued to influence labour relations. Derk Bodde has observed how different was the basis of Chinese guilds to those of north-west Europe. In Europe, merchant guilds developed on a non-kinship basis, while in China guilds were based on family and place of birth.[465] One example was the Wei 魏 clan, who offered their services to rebuild kilns at the imperial factory after the city had been razed during the Revolt of the Three Feudatories in +1674.[466] The government decreed that the Wei clan would retain hereditary rights over contracts for bricklaying and repairs at twenty private kilns that fired imperial wares.[467] The Wei family were said to have come to Ching-te-chen in the Yuan period, and their skill in bricklaying plus the quality of their mortar was much admired.[468] In the early +19th century several kiln owners attempted to copy Wei building methods, but the porcelain fired in these imitation constructions often warped or cracked; it as rumoured that only kilns built by the Wei clan could set kiln owners' minds at

[463] *Kung Chung Tang Chhien-Lung Chhao Tsou Che, Tshe* 12, p. 4.

[464] Anon. (1959a), pp. 120–3.

[465] Bodde (1991), p. 221, notes the kinship weakness of Indo-Europeans of Western (and particularly north-western) Europe, that led to the formation of non-kinship sworn brotherhoods to provide fellowship and mutual assistance. From these associations eventually emerged the merchant guilds of medieval Europe. In China, on the other hand, kinship ties always retained their primacy down to recent times, while merchant guilds, although they existed, never achieved the power or independence of their European counterparts. Nevertheless, the Chinese guilds could, within their particular localities, play significant roles both as maintainers of discipline among their members and as protectors of the interests of these members in dealings with the outside world, especially officialdom.

[466] *Fu-liang Hsien Chih* (1682 edn), ch. 3, p. 62b.

[467] *Jao-chou Fu Chih* (1872 edn), ch. 3, p. 63a.

[468] *Ching-te-chen Thao Lu*, ch. 4, pp. 5b–6a.

rest.[469] Although their reputation was undoubtedly deserved, it is probable that the Wei family protected their monopoly by encouraging such homilies.

Within specialist kilns and workshops themselves, labour was demarcated. Extremely precise divisions of labour were in place by the time that Lan Phu 藍浦 wrote his *Ching-te-chen Thao Lu* (An Account of Ceramic Production at Ching-te-chen, +1815) in the +18th century. He listed them in some detail, together with linked ancillary trades such as providers of clay and fuel.[470] For example, the supply of clay depended on the Clay Guild (*Pai-thu Hang* 白土行) who maintained a monopoly over distribution to kiln owners, who in turn depended on traders and brokers.[471] Fuel guilds (*Chhai Hang* 柴行 pine-faggot guild, *Chha Hang* 差行 brushwood guild) together with a water transportation guild (*Shui-yeh Hang* 水業行) collected scrub from the hills and sawed logs into halves or quarters and floated them downstream. Charcoal providers for the muffle kilns had their own guild (*Than Hang* 炭行), though the volume of sales was much smaller than that of the firewood guilds. Nevertheless, taken as a whole demand for firewood for the kilns caused massive deforestation. As early as the Southern Sung dynasty, Chiang Chhi 蔣祈 had expostulated on the mismanagement of natural resources and the destruction of nature.[472] By the Chhing dynasty, wood had to be shipped in from 100 miles away. Fuel consumption and costs were enormous. For example, in the +17th century they consumed one-third of the expenditure of the imperial factory.[473]

Control of workers was strict, with responsibility vested in the heads of each workshop. Folk memory recorded such aspects of day-to-day business in song:[474]

Anything to do with work on blanks, ask the nosey potter
The chief checks to make sure that everyone is present.
In the third month when there's money he weighs up market share
At the end of the year when the warehouses are full, lazy workers do well to worry.

坯工多事問坯頭
首領稽查口類周
三月有錢稱發市
年終棧滿惰工愁.

By the late Chhing dynasty, owners of ceramic businesses had to be members of one of the guilds, or form a partnership in which one of the members belonged (see pp. 771–2).

[469] *Ching-te-chen Shih Ti Ming Chih* records 28 family surnames associated with different areas of the industry during the Ming dynasty, with three more (*Ma* 馬, *Fang* 方 and *Yang* 楊) coming into prominence at the end of the period, see Liang Miao-Thai (1991), p. 17.
[470] *Ching-te-chen Thao Lu*, ch. 3, pp. 1a–4b.
[471] *Fu-liang Hsien Chih* (1682 edn), ch. 2, p. 5a.
[472] Pai Khun (1981), p. 42.
[473] *Fu-liang Hsien Chih* (1682 edn), ch. 4, p. 45b.
[474] This song is no. 12 in a section on management at the kilns, in the book of popular songs collected at Ching-te-chen by Kung Shih 龔軾, *Ching-te-chen Thao Ko* (+1824). See Yang Ching-Jung (1994), pp. 34–5.

Technological Development of Ching-te-chen Porcelain

Having reviewed the economic and social history of Ching-te-chen, technological developments will be considered. The distinctive white porcelain which led to the region's significance was first developed during the Five Dynasties period. As described above on p. 201, excavation near to Ching-te-chen suggests that kilns in this area began making high-temperature wares in the Five Dynasties period, mostly Yüeh-type ash-glazed stonewares of a typically southern siliceous type.[475] Early Ching-te-chen stonewares have dark-grey bodies and slightly bluish grey-green glazes. Bowls, ewers and dishes were the main products, and most wares were fired without saggers in dragon kilns. The wares were raised from the kiln's floor on short thrown columns, and separated from one another by small lumps of quartz-grains or sandy clay.

It is against this background of stoneware production that locally made white porcelain first appeared in the south, and four important Five Dynasties kilns making whitewares have now been investigated. They are mainly in the South river area at Hu-thien, and at more rural sites amongst the low rocky hills that surround the town, at Huang-ni-thou 黃泥頭, Yang-mei-thing 楊梅亭 and at Pai-hu-wan 白虎灣, with Huang-ni-thou being the largest and the best preserved.[476] These sites have yielded examples of the very earliest examples of white south Chinese porcelain, in some cases plainly visible on the ground's surface intermixed with grey-green glazed stonewares of the same date. The presence of porcelain and stoneware in the same spoil-heaps suggests that they may well have been fired in the same kilns, probably to temperatures between 1,230 and 1,260°C, far lower than contemporary northern porcelains. Bowls and ewers are the dominant forms, and some porcelain bowls show an influence from northern whiteware. Southern white porcelains were exported almost from the outset, and early +10th-century southern whitewares have been found in the Middle East, in association with the more abundant northern materials.

The Five Dynasties sites near to Ching-te-chen therefore seem to mark the actual transition from ash-glazed stoneware to true porcelain in southern China. With the appearance of white porcelain at Ching-te-chen, the making of Yüeh-type stoneware declined sharply in the district, and white porcelain became established as Ching-te-chen's prime ceramic production.

Perhaps the most impressive aspect of Ching-te-chen Five Dynasties whiteware is the extreme whiteness, purity and translucency of its fabric. This makes it an obviously different material from southern stoneware, without the blurring of boundaries that complicates discrimination between high-fired wares in the north (Table 34).

[475] Liu Xinyuan (1992), pp. 43–4, dismisses rumours about Han and Thang dynasty kilns in Ching-te-chen, stressing the unreliability of cited literary sources and stating that: 'Over the last 30 years, Chinese scholars, particularly the ceramic archaeologists at Jingdezhen [Ching-te-chen] have surveyed every village in the city and in Fuliang [Fu-liang]. Thus far not a single piece of Tang [Thang] porcelain fragment has been found in conjunction with potter's implements, and much less have remnants of any Tang [Thang] kilns been found.'

[476] *Ibid.*, p. 35.

Table 34 *Ching-te-chen greenware and Ching-te-chen whitewares of the Five Dynasties period*

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Total
Five Dynasties stoneware[a]	75.2	16.9	1.2	3.6	0.4	0.6	2.4	0.1	0.02	0.05	100.5
Five Dynasties porcelain[b]	77.5	16.9	trace	0.8	0.8	0.5	2.6	0.35	0.14	-.-	99.6
Five Dynasties porcelain[c]	75.8	18.3	0.2	1.0	0.7	0.8	2.4	0.4	-.-	-.-	99.6

[a] Kuo Yen-I *et al.* (1980), p. 235, table 2.
[b] Chou Jen & Li Chia-Chih (1960a), table 1, p. 53. (Described as Thang dynasty but probably early +10th century.)
[c] *Ibid.*



Fig. 47 Dish with white glaze, in imitation of Chinese porcelain, made in Iraq

As with the materials from Hupei province described on pp. 181–3, there is a surprising overall agreement between the oxide figures for the Ching-te-chen stonewares and porcelains, though vital differences exist in the levels of iron and titanium oxides. These account for both the whiteness and the translucency of the porcelain with the low titanium dioxide level in particular playing a crucial role in these effects. Entirely new raw materials in Chinese ceramic production appear to have been identified and used at Ching-te-chen for porcelain-making in the early +10th century and these rocks became the basis for the world's most developed porcelain tradition. However, very recent work suggests that use of this type of porcelain stone may have been anticipated in Korea in the early +9th century, particularly at the important south Korean sites of Pangsan-dong and Sori in Kwangju district (near Seoul).[477] Similar raw materials were eventually discovered in Japan in the late +16th or early +17th centuries, making these early Korean whitewares precursors, not only to Ching-te-chen whitewares, but also to the vast tradition of East Asian porcelain manufacture with high-silica micaceous materials.

THE NATURE OF CHING-TE-CHEN FIVE DYNASTIES WHITEWARE

The true nature of Ching-te-chen's Five Dynasties whiteware is perhaps best approached by comparing its fired analysis to modern examples of Ching-te-chen raw materials that have been investigated mineralogically. Three papers in particular have proved useful for this work, all products of Western attempts to understand the true nature of Chinese porcelain. Details of the first study, published by Georges Vogt in +1900 using samples collected by Georges Francisque Fernand Scherzer, have already been noted on p. 38.[478] The second and third studies by Russian scientists G. L. Efremov, L. N. Nikulina and T. I. Taraeva, were made more recently. Their shorter papers on Ching-te-chen raw materials were compiled at the time of the Sino-Soviet *accorde*.[479] Efremov's paper appeared in +1956, and Nikulina's and Tataeva's in +1959.

VOGT'S PAPER

Georges Vogt's work has proved central to the understanding of southern Chinese porcelain. His agent Scherzer had operated under some difficulties during a three-week 'field trip' to Ching-te-chen in November +1882, where he was harassed by local potters and obstructed by officials, who were correctly suspicious of his

[477] See Koh Choo *et al.* (1999), pp. 52–3; Koh Kyong-Shin (2001).
[478] Vogt (1900), pp. 560–612.
[479] Efremov (1956), pp. 28–30; Nikulina & Taraeva (1959), pp. 455–60.

motives.[480] However he persisted in his mission, and eventually shipped back to Paris glaze and body raw materials, contemporary recipes, and Ching-te-chen porcelains made from known materials. The extended analytical report and commentary by Vogt, based on Scherzer's samples and notes, still stands as the most complete scientific account of Ching-te-chen porcelain technology yet published.

Vogt's main findings were that late +19th-century Ching-te-chen porcelains were micaceous rather than feldspathic, and that the firing temperatures used for porcelains in China (*c.* 1,250–1,310°C) were modest by European hard-paste standards. As a legacy of the Meissen experiments, firing temperatures for typical French and German porcelains in Vogt's time ranged from about 1,350°C to 1,410°C, as they still do today.

The micaceous nature of Ching-te-chen porcelain was a particular surprise to Vogt as Ching-te-chen raw materials had been studied at Sèvres earlier in the +19th century and declared to be feldspathic. This error seems to have been caused by the fine grain-size of the Chinese rocks, and the consequent difficulties in distinguishing their constituent minerals.[481] This 'feldspar fallacy' has proved difficult to displace, and the mistaken belief that Chinese porcelains are fluxed with feldspar persists in many modern writings on the subject (see also pp. 711–12, 773–4 in Part 7 of this volume).[482] Vogt described the micaceous material that he found in Chinese porcelain stone in the following manner:[483]

> The greatest part of the white mica . . . in general for the Chinese rocks that I have studied, is of such fineness that neither the naked eye nor the hand lens can perceive it; which explains how its presence escaped observation by Ebelman and Salvetat . . . they identified these rocks as petro-silex or compact feldspar.

We now know that most of the mica in Chinese porcelain stone is in the form of sericite (named from its silky appearance) a mineral that is also known as *hydromica* or *illite* (see note a, p. 46 for a discussion of the 'illite question'). The mineral contains less potassium and more water than primary potassium mica (muscovite), the platy mineral that provides the silvery sparkle in polished granite (Table 35).

[480] Because of Ching-te-chen's traditional distrust of visitors, the local magistrate suggested that Scherzer might prefer to look around the workshops at night. However, the magistrate had to leave town on business, which allowed Scherzer more liberty to observe porcelain production at first hand and to collect samples. Vogt (1900), pp. 533–4. Scherzer wrote to his friend Dr Stephen Bushell that he could hardly venture to look out from his closed sedan chair without being pelted with potsherds. Bushell (1899), p. 291.

[481] Ebelman & Salvetat (1851), p. 285, wrote: 'Les petuntsé ont une composition chimique très-voisine de la composition moyenne de la pegmatite du Limousin, mais leurs caractères minéralogiques les identifient avec le feldspath compacte on pétrosiliex.'

[482] Sundius & Steger (1963), pp. 414, 502–3; Medley (1976), p. 14; Satō (1981), p. 124.

[483] Tichane (1983), pp. 223–4, translating Vogt (1900). What Vogt actually wrote on p. 549 was: 'La plus grande partie du mica blanc . . . En général dans les roches chinoises que j'ai étudiées, est d'une telle finnesse que ni à l'oeil nu, ni à la loupe on ne peut lapercevoir; ce qui explique que sa présence d'Ebelman et Salvétat . . . ils identifiérent les roches chinoises avec les petro-silex ou feldspaths compact.'

Table 35 *Comparison of muscovite and illite (primary and secondary white mica)*

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	Loss	Total
Theoretical muscovite[a]	45.2	38.4	-.-				11.8		4.5	99.9
Typical muscovite[b]	45.6	36.7	-.-	2.3	0.2	0.4	8.8	0.6	5.0	99.6
Typical illite (hydromica)[c]	56.4	33.8	0.07	0.45	0.7	1.3	6.7	0.5	6.5	100.1
Mica in Ching-te-chen porcelain stone[d]	46.7	35.8	-.-	2.1	0.3	0.5	7.3	0.5	6.8	100.0

[a] Vogt (1900), p. 548.
[b] Johnstone & Johnstone (1961), p. 377, table 121 (a muscovite from Bengal).
[c] Mattyasovszky-Zsolnay (1946), p. 255, table 1.
[d] Vogt (1900), p. 560.

Table 36 *Comparison of +1882 Ching-te-chen 'single-rock' porcelain and early +10th-century Ching-te-chen whiteware*

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	Total
+1882 Ching-te-chen porcelain[a]	76.0	18.0	-.-	1.0	0.2	0.2	4.1	0.4	100
Five Dynasties whiteware[b]	75.8	18.3	0.2	1.0	0.7	0.7	2.4	0.4	99.5

[a] Vogt (1900), p. 560.
[b] Chou Jen & Li Chia-Chih (1960b), p. 53, table 1.

Table 37 *Comparison of +1959 Ching-te-chen Nan-khang porcelain stone and Ching-te-chen Sung* chhing-pai *ware*

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	(K_2O+Na_2O)	Total
Nan-khang stone (fired)[a]	77.5	16.6	0.07	0.6	0.8	0.4	3.2	0.85	(4.05)	100
Sung *chhing-pai* porcelain[b] (Average of three samples)	77.9	16.2	0.07	0.6	0.8	0.2	3.1	1.0	(4.1)	99.9

[a] Nikulina & Taraeva (1959), p. 457.
[b] Wood (1986), p. 262.

The last analysis is of the ultra-fine mica extracted by Vogt from a prepared sample of an +1882 Ching-te-chen porcelain stone. This analysis is nearer in composition to hydromica than to muscovite, and Vogt established the mineralogy of this example of prepared porcelain stone to be: quartz 47.7; kaolinite 14.00; white mica 32.5; and sodium feldspar 5.8.[484] This particular stone was used, unmixed with any other material, to make the body for late +19th-century turquoise-glazed porcelain. Although its true clay content was low (14% kaolinite) the slight plasticity of the platy hydromica offset this deficiency to some degree. The full, fired, analysis of this 'single-rock porcelain' can be compared with an example of +10th-century Ching-te-chen whiteware (Table 36).

The good match between the two materials suggests that Ching-te-chen Five Dynasties whiteware may well have been made from a single kaolinised porcelain stone, after suitable crushing and washing techniques had been applied to the raw rock. Further parallels with modern Ching-te-chen raw materials, and the early porcelains of the Ching-te-chen district, have been cited. For example, the material known as Nan-khang 南康 porcelain stone, described in detail in the Russian report of +1959, has a strong compositional similarity to the Sung and Yuan dynasty Ching-te-chen *chhing-pai* ware. This highly translucent ware, with an icy bluish glaze, was developed from Five Dynasties whiteware at Ching-te-chen in the later +10th century. It then became a mainstay of Ching-te-chen porcelain production until the early +14th century (Table 37).[485]

A particularly useful feature of this match is the detailed geological, mineralogical and ceramic analyses of Nan-khang stone presented in the Russian paper. The mineralogy of Nan-khang stone was established as: quartz 58; sericite 28; kaolinite 10 and carbonate (Ca+Mg) 4 (there was no feldspar). The material needed 25% of water to make it plastic, and it shrank 4% linear in drying. Linear shrinkage increased to 10% after firing to 1,250°C, and the refractoriness of the prepared stone (that is its melting-point) was found to be 1,540°C, although it began to distort at 1,280°C. Nan-khang stone was a useful supplementary ingredient to Ching-te-chen porcelain in the +1950s, but the ceramic properties established by Nikulina and Taraeva also show the great potential of this type of material for the manufacture of translucent white porcelain from a single, prepared rock.

The Geology of Ching-te-chen Porcelain Stone

The petrological assessment of Ching-te-chen porcelain stone by the Russian scientists is also worth quoting in detail, as it the fullest account yet published for this kind of material:[486]

[484] *Ibid.*, p. 561.
[485] Wood (1986), p. 262. Five Dynasties to Yuan dynasty *chhing-pai* wares are discussed also on pp. 556–60
[486] Nikulina & Taraeva (1959), p. 458.

The Chinese porcelain stone represents a metamorphosed acid effusive rock of the secondary quartz type . . . their primary rocks might have been lava, tuff or pyroclastic rocks. As is known the first consist of glass with porphritic crystalline phenocrysts, the second of volcanic ash and the last from fragments of effusive rocks cemented together with ash. Secondary conversions characteristic of all these are as follows: devitrification – the decrystallization of the glass and cementing ash, which is frequently accompanied by silification, and decomposition with the segregation of neogenic minerals (sericite, carbonates and ferric hydroxides). As a result of these processes the primary characteristics of the original rock are frequently almost entirely destroyed. Their secondary silification imparts density and strength. Subsequent profound change in these rocks might proceed toward their conversion into clay through the kaolinisation of the main constituent minerals.

This last point is of particular importance for the understanding of early Ching-te-chen porcelains as both Nan-khang stone and the 'turquoise body' studied by Vogt were unusual in being so highly kaolinised. Most other porcelain stones, used for porcelain-making at Ching-te-chen in the late +19th and mid +20th centuries, were lower in both kaolinite and hydromica and therefore practically non-plastic. However, their non-plastic natures were improved by mixing them with a clay-rich primary material known as *kao-ling*, the origin of our word kaolin. Kaolin is the anglicised version of the name of one of the hills from which porcelain stone was mined, called *Kao-ling* 高嶺 (high ridge), and situated some 50 kilometres north-east of Ching-te-chen. 'Kao-ling' was not used as a description of a porcelain raw material in China till the Chhing dynasty, when the hill became the main source of porcelain stone (see p. 236).[487] Etymologically speaking, therefore, the Western term derives its meaning from a late stage in the Chinese porcelain story.

Non-kaolinised porcelain stones were more fusible than the kaolinised types, due to their high levels of sodium feldspar (albite), but this characteristic was offset by additions of the less fusible kaolin. These differences in firing behaviour led Ching-te-chen potters to refer to the more refractory clay-rich kaolin material as the 'bones' of their porcelains, and the more fusible porcelain stones as their 'flesh'.

This binary approach to porcelain manufacture seems to have started at Ching-te-chen sometime in the Yuan dynasty, when it is thought that the practice of blending non-kaolinised porcelain stone with a clay-rich material was introduced. The subsequent development of these mixed clay-rock recipes is described in due course but, before this time, 'one rock' porcelains appear to have held the stage as the universal southern type. The huge growth in white porcelain production that occurred in southern China in the +10th to +11th centuries seems to have depended on the discovery and exploitation of deposits of kaolinised porcelain stones throughout the area. Once their potential was appreciated, use of the material was quickly adopted in provinces as various as Anhui, Hupei, Fukien, Chekiang, Kuangtung and Kuangsi.[488] The minor compositional differences that occurred between the different kaolinised rocks supplied distinctive characters to the local wares.

[487] Liu Hsin-Yüan & Pai Khun (1982), pp. 152–6.
[488] Luo Hongjie (1996), database.

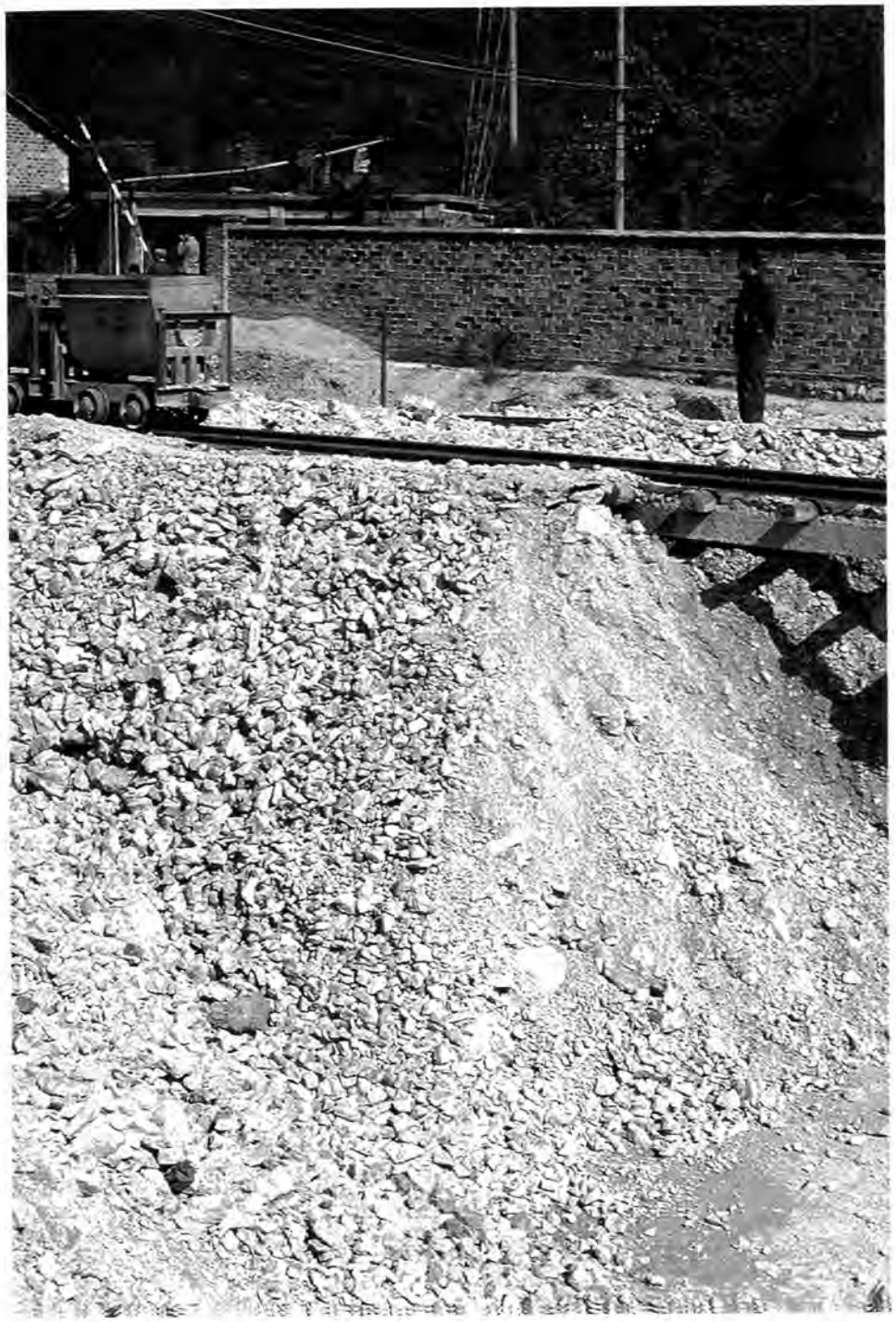


Fig. 48 Porcelain stone mined at Liu-chia-wu 劉家塢, +1982

Table 38 *East Asian porcelains thought to have been made from quartz-mica rocks*

Province	Kiln site	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	Date	Total
	Ching-te-chen											
Chiangsi	Hu-thien[a]	77.0	18.0	-.-	0.8	0.6	0.35	3.0	0.25	0.1	Five Dynasties	100.1
Chiangsi	Hu-thien[b]	76.2	17.6	0.06	0.6	1.4	0.1	2.8	1.0	0.03	Sung	99.8
Chiangsi	Nan-shih-chieh 南市街[c]	80.6	15.3	0.03	0.5	0.5	0.2	2.6	0.2	0.08	Southern Sung	100.0
	Te-hua[d]											
Fukien	Kai-te 蓋德	81.6	14.9	0.09	0.9	0.1	0.1	2.9	0.08	-.-	Southern Sung	100.7
Fukien	Kai-te	77.8	18.5	0.03	0.4	0.2	0.2	4.45	0.10	0.03	Southern Sung	101.7
Fukien	Chhü-tou-kung	76.4	17.4	0.08	0.3	0.04	0.06	5.7	0.10	0.03	Yuan	100.1
Fukien	Tsu-lung-kung	76.7	16.8	0.10	0.35	0.15	0.08	5.9	0.13	0.03	Ming	100.2
Fukien	*Chien*[e]											
Fukien	Chien	79.95	14.5	0.04	1.1	0.4	0.1	3.6	0.6	0.2	Southern Sung	100.5
Fukien	Chien	73.9	20.00	0.05	1.3	0.2	0.2	4.7	0.03	0.02	Southern Sung	100.4
	Lung-chhüan											
Chekiang	Lung-chhüan[f]	74.1	18.2	0.01	1.6	0.3	0.1	4.9	0.7	-.-	Northern Sung	99.9
Chekiang	Ta-yao[g]	71.6	20.9	0.2	2.1	0.2	0.2	4.5	0.2	0.02	Southern Sung	99.9
Chekiang	Ta-yao[h]	70.4	22.1	0.2	1.8	0.04	0.15	4.9	0.3	0.06	Yuan	100.0

	Jung-hsien[i]											
Kuangsi	Jung-hsien	70.1	22.2	0.03	1.2	0.5	0.7	5.0	0.1	0.07	Northern Sung	99.9
Kuangsi	Jung-hsien	70.0	23.7	0.02	1.1	0.1	0.6	4.9	0.1	0.05	Northern Sung	100.6
	Chhao-chou											
Kuangtung	Chhao-chou[j]	70.8	22.2	0.2	0.9	0.3	0.3	4.38	0.1	-.-	Sung	99.2
	Wu-chheng[k]											
Hupei	Wu-chheng	74.1	19.6	0.2	0.8	1.0	0.2	4.0	0.1	0.1	Five Dynasties	100.1
Hupei	Wu-chheng	72.6	21.6	0.2	0.7	0.6	0.1	3.7	0.1	0.1	Five Dynasties	99.7
KOREA	Usanni[l]	72.2	19.6	0.06	0.8	0.5	0.4	3.9	1.7	0.05	Choson	99.2
JAPAN	Arita[m]	74.7	18.7	0.07	1.0	0.2	0.15	4.2	0.95	-.-	+17th C	100.0

[a] Chou Jen & Li Chia-Chih (1960b), p. 53.
[b] *Ibid.*, p. 53, table 1.
[c] Research Laboratory for Archaeology and the History of Art, Oxford.
[d] Four Te-hua body analyses from Guo Yanyi & Li Guozhen (1986), p. 143, table 1.
[e] Chang Chih-Kang *et al.* (1999a), p. 146, table 2.
[f] Chhen Yao-Chheng *et al.* (1980), pp. 544–8, table 3 (from base of Ching-sha pagoda dated +977).
[g] Research Laboratory for Archaeology and the History of Art, Oxford.
[h] *Ibid.*
[i] Zhang Fukang *et al.* (1992a), p. 376, table 1.
[j] Guangdong Provincial Museum (1982), p. 92.
[k] Luo Hongjie (1996), database.
[l] Koh Choo *et al.* (2002), p. 200, table 1.
[m] Pollard (1983), p. 158, table 3 (average of 85 +17th-century Arita porcelains).

Given the ubiquity of this material it seems odd, in retrospect, that southern white porcelains were so late in their introduction. Related but more iron-rich materials had already seen extensive use in southern China for thousands of years. A strong theme of conservatism runs through the history of Chinese ceramics, and it is against this background that many of the more significant ceramic innovations have to be viewed.

The unusual consistency in early porcelain composition in southern China is impressive, and can be compared with that established for southern siliceous stoneware (see Table 38), of which early south Chinese porcelain seems a close relation. It is also interesting to see how similar the Chinese bodies are to typical Korean and Japanese white porcelains, materials that began production in the +9th century and early +17th century respectively.[489] Korean and Japanese white porcelains were largely quartz-kaolinite-mica mixtures, and their geological origins show parallels to the Ching-te-chen materials. The Korean material, for example, has been described as a *tuff*, that is compacted volcanic ash,[490] while the Japanese Izumiyama stone 泉山陶石 of north Kyushu 九州 (near Arita 有田), is an altered igneous rock of volcanic origins.[491] After continuous exploitation since the +17th century what was originally a small mountain at Izumiyama is now a large terraced crater. It seems likely that the alteration of Izumiyama stone, mainly from feldspar to sericite, was a hydrothermal process acting from deep in the centre of the mountain outwards, forming concentric zones of alteration. In the mountain's core the stone was rich in sericite, while further out the less-altered rock contained more feldspar.[492] Similar zonal alteration processes have been proposed to explain the various types of porcelain stone at Ching-te-chen, as Tite *et al.* explain:[493]

> This variation occurs because the raw materials represent products of the alteration of pre-existing quartz feldspar rocks by high-temperature saline hydrous fluids . . . Typically sericitized rocks and kaolinised rocks are adjacent in a zonal body with a gradational contact (i.e. kaolinised porcelain stone).

The most obvious common features of these early southern porcelains are their highly siliceous natures, their low titania levels, their high potassium oxide contents, and their very low sodium oxide percentages. The original rocks appear to consist mainly of quartz, hydromica and clay, with very low contents of feldspar, particularly the sodium feldspar, albite. The high quartz contents of the rocks (*c.* 50–60%) gives a characteristically 'sugary' fracture to early southern porcelains, while their levels of potassium oxide dictated their translucency. Where these were high, the

[489] Koh Kyong-Shin (2001); Impey (1998), p. 2.

[490] Koh Choo (1992), pp. 637–8. The author describes modern Korean porcelain stones as follows: 'These raw materials . . . can be made into ceramic bodies singly as they are. Such a practice for using a single raw material as a ceramics body is called Tanmi (單味) meaning a single flavour. These raw materials can be inferred to be similar to the Chinese porcelain stones, which provide both plasticity and flux in the form of sericite.'

[491] Yoshida Naojiro & Fukunaga Jiro (1962), p. 36.

[492] *Ibid.*, p. 36.

[493] Tite *et al.* (1984), pp. 147–8.

porcelains could be very translucent indeed. Firing temperatures probably fell within the 1,220–1,270°C range and the porcelain bodies richer in iron were fired in reduction to avoid a yellowish cast.

It is likely that these new southern porcelains were weaker materials than the high-fired clay-rich porcelains still being produced in north China. The differences are well summed up by the remarks of Hermann Seger in the late +19th century, when comparing his new 'Seger Porcelain' (based on analyses of Japanese porcelain, and similar to early south Chinese porcelain) with contemporary German hard-pastes:[494]

> It, like all translucent porcelains of Asia, is more sensitive to quick change in temperature and to a sharp knock than our ordinary porcelain, richer in alumina.

MINING

Porcelain stone was known as '*thou-un-tzu*' (current, local pronunciation for *pai-tun-tzu* 白墩子) in many texts, from whence comes the English word 'petuntse'. *Nan Yao Pi Chi* (Notes on Southern Kilns, *c.*+1725–35) cited four locations in Chhi-men county 祁門縣 in Anhui province as producing the best-quality porcelain stone of all, with two further locations yielding second-quality rock. We know that fine white clay from Anhui was important in the manufacture of architectural ceramics (p. 514). Naturally, Chiangsi province also supplied porcelain stone from several deep mines to Ching-te-chen.[495] *Thien Kung Khai Wu* (+1637) noted that wares were made from a mixture of porcelain stone from Kao-liang mountain 高梁山[496] and porcelain clay from Khai-hua mountain 開化山.[497] Modern scholars have judged from several sources that the main sources of porcelain stone in Chiangsi province were Yü-kan 余干 and Kao-ling, and that stone-dust from Hu-thien was also used.[498]

Sung dynasty porcelain stone mines near Ching-te-chen can still be seen as dips in the ground, although whether these are overgrown open-cast quarries or collapsed underground workings is hard to tell.[499] Both mining methods are used today at Ching-te-chen, with the kaolinised Nan-khang stone being won from a large terraced quarry.[500] Some underground mines within a 20–50 kilometre radius of Ching-te-chen can be as deep as 240 metres and can contain excavated chambers that are between 100 and 200 metres wide, exploiting porcelain stone seams that may be 30–40 metres deep. In +1980 three of these underground mines between them produced some 36,000 tonnes of stone, and they have combined reserves of at least 100 years.[501]

[494] Seger (1902d), p. 725.
[495] *Nan Yao Pi Chi* ('Kao Ling'), p. 7b/324.
[496] Today's Kao-ling.
[497] *Thien Kung Khai Wu*, ch. 7, p. 6a. Sun & Sun (1966), p. 147.
[498] Fu Chen-Lun (1993b), p. 12.
[499] Observed by the authors at Ching-te-chen in +1982.
[500] Efremov (1956), p. 490.
[501] Footnote by John B. Wachtman Jr. in Murray (1980), p. 921.

PREPARATION

In its raw state Chinese porcelain stone varies from being tough and vitreous, with a slight greenish hue, to being weathered and crumbly, but the material always needs thorough preparation to realise its plasticity. At Ching-te-chen and Te-hua the traditional refining techniques with porcelain stone were generally processed in the manner described below.

First, large lumps of porcelain rock were broken by hand-hammers into pieces less than five centimetres across. The broken rock was then crushed dry by large water-powered trip hammers, and the resulting powder cast into tanks of water and thoroughly stirred with wooden paddles. Another method was to utilise animal power, which in the case of south China was provided by the strong and gentle water buffalo. The animal would be led round and round a small pond, treading the rock into a fine powder beneath its hoofs.[502] This process seems intimately connected to China, and it is interesting to learn of another country whose ancient history, geology and use of livestock combined to manufacture pots in the same way. In Ballas, near ancient Nagada in the upper Nile valley, +20th-century potters utilise clay-rich shale for ceramics. They dump small pieces into stone-lined pits, hydrate them for a day, and then set water buffaloes to render the material down.[503]

At Ching-te-chen, once the crushed rock had received preliminary pounding it was tipped into tanks of water, the finer material forming a frothy scum on the water's surface. This was skimmed and slopped into another tank, a process that might be repeated a number times. The decanted material was then allowed to settle and the clear water drained away, after which the material was thickened by evaporation. The white muddy powdered stone was then dipped out and allowed to stiffen on a bed of newly fired bricks. When the prepared stone reached the consistency of stiff mud it was moulded into standard brick sizes and, sometimes, stamped with the name of the quarry source.[504]

The dry bricks were then transported to the porcelain workshops where the material often underwent further refining before the potters could use it. The large amounts of coarser material that sank at the 'froth flotation' stage were sometimes returned for recrushing, sometimes discarded, and sometimes used as fillers in kiln-setters, or as a white sandy temper in coarser wares.

Ching-te-chen Thao Lu (+1815) gave a great deal of very detailed information about clay sources and potting, reiterating material from earlier sources. It noted that the clay used for ceramics always had to be made from rock, collected by local people

[502] Process observed by the authors in an outlying district of Ching-te-chen in +1982.

[503] The industry at Ballas has links with ancient Egypt of the pre-dynastic period (*c.* −4,500 to −3,100), when the craft of pottery-making was at its height. The potteries operate during the agriculturally unproductive months of spring and early summer, before the time of harvest when high temperatures and excessive dryness render potting impractical. The richest men in the village are those who own the water buffaloes. Romer (1982), pp. 44–7.

[504] Processes observed by the authors at Ching-te-chen in +1982 and at Te-hua in +1995.



Fig. 49 White porcelain bricks at Ching-te-chen, +1986

who built sheds and used mountain streams to turn the wheels that tripped the hammers used to pound the rock to powder. When split these rocks displayed black markings like the deerhorn plant (*lu-chiao tshai* 鹿角菜). Various locations where mines were opened (including Kao-ling) were mentioned, the mines giving their names to different porcelain stone varieties. The rock was rendered down in spring, when there was a lot of water flowing down hill streams into each processing shed, to keep all its trip-hammers in operation. Later in the year, when the force of the streams was not so strong, several pestles were taken out of use. When the force of the water flowed evenly the pounded rock was converted into dense, fine powder, but when the streams ran slowly the hammers did not pound down so vigorously and the pulverised rock was coarser. Thus the best porcelain stone paste and the best vessels tended to be manufactured in the spring.[505] Clay was further purified by putting it into a tub of water, stirring it with a wooden rake, and then skimming off the floating sediment with a fine hair sieve. Next it was passed through a double layer of fine gauze, the liquid clay being pressed down by a brick paddle with a fine cloth base. When dehydrated in this way, the clay was pounded and stirred into a fine mass.[506] The processed clay and rock came in several qualities, ranging in colour from white through red

[505] *Ching-te-chen Thao Lu*, ch. 4, pp. 2a–b.

[506] From description to illustrations 1, 2, 3, 4, 6, 7, 8 in *Ching-te-chen Thao Lu*, ch. 1, pp. 2b–6b. Sayer (1951), pp. 4–7.

to yellow.[507] The red and white types were used for fine ware, the yellow for coarse ware. The roughest ceramics of all were composed of 'sweepings', the residue left in the bottom of sedimentation tanks. When relevigated this was usable. A type of extremely refined kaolin called *hua-shih* 滑石 was used for small, intricate, carved and ornamental pieces, such as pure, white 'bodiless porcelain' (*tho-thai* 脫胎). This ware was first made in the Yung-Le reign period, was known in the Chheng-Hua and Wan-Li reign periods, and an even thinner type, as thin as Chinese paper, was manufactured in the +18th century.[508]

Chiangsi Sheng Ta Chih (+1597) recorded that 60% of 'official clay' and 40% of porcelain stone from Kao-ling was used for fine wares. For large cisterns broken sherds from Yü-kan were added, along with stone-dust from Hu-thien which made the material very strong. Material from Yü-kan was more pliable and more refractory than that from Kao-ling, making it suitable for very big vessels like cisterns.[509] The processed porcelain stone was moulded into square bricks and transported to Ching-te-chen on small boats, was then again put into a pit and pounded for a whole day, then placed in a large cistern to be sorted by water. Coarse particles sank, and the fine particles that were left in the upper part of the water were poured into a second tank. Material in the second cistern was sorted once more, which resulted in a suspension of extremely fine-particled liquid that was poured into a third cistern. This mixture was poured into a rectangular tank built of bricks beside the kiln, borrowing kiln heat to dehydrate the clay mixture. When the mixture had dried, it needed to be rehydrated to form a paste for potting with.[510] This double- and triple-levigation method was extremely similar to that employed at Lung-chhüan 龍泉 (see pp. 439–40).

THE EFFECTS OF REFINING PORCELAIN STONE

Porcelain stone before and after preparation is obviously a different material and useful data have been published to show the changes in composition effected by these crushing and 'washing' processes. Both Ching-te-chen and Lung-chhüan porcelain stones have been studied from this standpoint (Table 39).

These figures suggest that the porcelain stones used at Ching-te-chen changed little in their overall compositions during the refining process, despite large amounts of grit being discarded. This seems an odd result, given that the mineral balances of these rocks may change radically with particle–size. In Nan-khang stone, for example, the coarsest fraction (>0.05 millimetres) is roughly 75 quartz, 5 albite and 15 sericite, while the finest fraction (0.005–0.001 millimetres) is 40 quartz and

[507] Both red and yellow colourings would have been caused by iron impurities. In fact, porcelain stone and clay occur in a variety of colours in the natural state; reddish, brown, grey, yellowish and white.
[508] *Ching-te-chen Thao Lu*, ch. 4, pp. 2b–4a. Cf. *Nan Yao Pi Chi*, pp. 7b–8a/324–325, for references to *hua-shih*.
[509] *Chiangsi Sheng Ta Chih* (1597 edn), ch. 7, pp. 5b–6a. Fu Chen-Lun (1993b), p. 14.
[510] *Thien Kung Khai Wu*, ch. 7, p. 6a. Sun & Sun (1966), p. 147.

Table 39 *Porcelain stones from Chiangsi and Chekiang provinces: before and after processing*

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	Loss	Total
Ching-te-chen area, Chiangsi[a]											
San-pao-pheng stone 三寶蓬石 (raw rock)	75.1	15.8	0.14	0.6	0.04	0.4	4.1	2.5	-.-	1.3	100.0
Briquette	75.0	15.45	0.02	0.6	0.5	0.3	3.0	3.5	-.-	1.5	99.9
Nan-khang stone 南康石 (raw rock)	74.3	16.9	0.1	0.6	0.9	0.35	3.15	0.3	-.-	3.7	100.3
Briquette	76.0	15.3	tr.	0.6	1.1	0.1	2.95	0.2	-.-	3.35	99.6
Lung-chhüan area, Chekiang											
Ta-yao stone 大窯石 (natural state)[b]	76.2	19.1	0.3	1.75	0.01	0.23	2.3	0.2	0.02	0.0	100.1
Ta-yao stone (refined)	73.6	20.7	-.-	1.9	0.4	0.5	2.5	0.4	0.03	0.0	100.1

[a] Nikulina & Taraeva (1959), p. 457.
[b] Chou Jen *et al.* (1973), p. 137.

60 sericite.[511] That the overall composition of the rock is maintained during preparation suggests that the processing of the stone involved some very effective crushing of the coarser fractions, rather than a simple liberation of the finer material at the 'froth flotation' stage.[512]

THE INTRODUCTION OF KAOLIN AT CHING-TE-CHEN

By the time that clay-rich materials were added to porcelain bodies at Ching-te-chen, kaolinised porcelain stones had already seen some three centuries of successful use as the district's main porcelain raw material. Kaolinised stones may have been intermixed before this time, but the use of clay-like materials as separate ingredients in Ching-te-chen porcelains, if it happened at all, was probably very minor. The main evidence for the adoption of clay as a supplementary Ching-te-chen body-material appears in porcelain compositions of the Yuan dynasty. It is during this period that some Ching-te-chen body and glaze analyses become noticeably richer in sodium oxide. This is a sign that lesser amounts of kaolinised porcelain stones are being used in the porcelain glaze and clay recipes. The change is evident in some later *chhing-pai* porcelains, but it is particularly noticeable in a group of Yuan dynasty *shu-fu* 樞府 porcelains from the Hu-thien kilns a few miles south of Ching-te-chen (Table 40).

[511] Efremov (1959), p. 491.
[512] Stannard (1986), p. 251, notes that in Nan Kung (*sic*) stone 'a high percentage of ~50μ mica in that "whole rock" has been reduced to at least <10μ material in the Briquette.'

Table 40 *Yuan dynasty Hu-thien* shu-fu *porcelains and their glazes*[a]

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	Total
Yuan Hu-thien *shu-fu* body	73.7	19.5	0.2	1.4	0.2	0.2	3.2	2.0	0.1	100.5
Yuan Hu-thien *shu-fu* body	72.7	20.7	0.2	1.2	0.1	0.2	2.7	2.4	0.1	100.3
Yuan Hu-thien *shu-fu* body	72.15	21.6	0.2	1.2	0.1	0.2	2.8	2.1	0.1	100.5
Yuan Hu-thien *shu-fu* glaze	73.4	14.6	trace	0.8	5.3	0.2	2.9	3.3	0.1	100.6
Yuan Hu-thien *shu-fu* glaze	72.7	15.2	trace	0.8	4.8	0.2	3.0	3.7	0.1	100.5
Yuan Hu-thien *shu-fu* glaze	72.0	15.6	trace	0.85	5.6	0.2	3.1	3.5	0.1	101.0

[a] Chen Xianqiu *et al.* (1983b), p. 16. (The data are from a poster-paper.)

Table 41 Shu-fu *glaze stone compared with San-pao-pheng stone*

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	Total
Average calculated *shu-fu* glaze stone[a]	76.25	16.0	-.-	0.9	-.-	0.2	3.15	3.4	0.1	100.0
Prepared San-pao-pheng stone (fired)[b]	76.2	15.7	0.02	0.6	0.5	0.3	3.1	3.6	-.-	100.0

[a] Author's figures (NW).
[b] Nikulina & Taraeva (1959), p. 457.

The sodium oxide figures in the above analyses show that high-albite porcelain stones were used in both *shu-fu* glazes and *shu-fu* bodies at Hu-thien. As most Ching-te-chen glazes have been made by adding limestone to glaze-stone, or to porcelain stone, subtraction of the calcia contents from the glaze analyses should show the type of porcelain stone used in the *shu-fu* glazes. If this approach is followed a good match appears between the *shu-fu* glaze stone and a well-known Ching-te-chen raw material known as San-pao-pheng 三寶蓬 stone, mined some fourteen kilometres south of Hu-thien (Table 41).

Calculations with mixtures of San-pao-pheng stone with a low-albite kaolin, in proportions from about 90-stone/10 kaolin to 80-stone/20 kaolin, supply body analyses somewhat similar to those established for Yuan dynasty Hu-thien *shu-fu* wares, but rather too high in sodium oxide, and too low in iron and titania (Table 42).

This may mean that the material added to albitic porcelain stone for making Yuan dynasty Hu-thien *shu-fu* wares was not quite a Ching-te-chen kaolin as we

Table 42 *Average* shu-fu *body-material compared with San-pao-pheng/kaolin mixtures*[a]

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	Total
Average of 5 *shu-fu* bodies (RLAHA Oxford)	72.9	20.2	0.07	1.1	0.3	0.15	2.8	2.4	0.1	100.4
SBP stone 90/low albite kaolin 10	74.0	19.75	0.01	0.9	0.05	0.2	3.1	3.1	0.1	101.2
SBP stone 85/low albite kaolin 15	72.8	20.4	0.01	0.8	0.075	0.2	3.1	3.0	0.1	100.5
SBP stone 80/low albite kaolin 20	71.7	21.0	0.01	0.7	0.1	0.2	3.1	2.9	0.1	99.8

[a] NW's calculations.

Table 43 *Hypothetical clay compositions that would result from the use of Hu-thien glaze stone in Hu-thien* shu-fu *porcelain bodies during the Yuan dynasty*

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	Total
'40% *shu-fu* clay' in fired weight %	66.9	27.7	0.44	1.67	0.34	0.19	2.56	0.04	0.02	99.9
'50% *shu-fu* clay' in fired weight %	69.5	25.6	0.36	1.54	0.28	0.04	2.72	0.72	0.04	100.8

understand it today. Calculation suggests that it could have been a less pure material than most kaolins so far analysed (Table 43).[513]

These figures may be compared with the prepared kaolins used at Ching-te-chen in more recent times, and described by such writers as Ebelman and Salvetat, Vogt, and Efremov.

It can be seen from Table 44 that some kaolins used at Ching-te-chen in the +19th century were high in Na_2O (and shown by Vogt to be rich in albite), while others were rich in K_2O, from potassium mica, both primary and secondary. Some again proved to be rich in both minerals. Iron oxide levels also range from relatively low figures (0.6%) to unusually high (2.7%). In these regards the kaolins used for porcelain-making at Ching-te-chen could show as much variation in their mineralogies and degrees of purity as the porcelain stones they were used with.

These new *shu-fu* style bodies were later used at Hu-thien for the manufacture of massive underglaze-blue decorated porcelains, particularly in the second half of the +14th century, much of it made for export to the Middle East (Table 45).

[513] Wood (2000b), p. 30.

Table 44 *Analyses of kaolins used at Ching-te-chen in the +19th and mid +20th centuries*

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	loss	Total
Ebleman & Salvetat[a]										
'kaolin de Sy-Kang'	55.3	30.3	-.-	2.0	-.-	0.4	1.1	2.7	8.2	100.0
'kaolin de Tong-kang'	50.5	33.7	-.-	1.8	-.-	0.8	1.9	-.-	11.2	99.9
Vogt[b]										
'kaolin de Ming-cha'	54.5	30.3	-.-	0.9	0.3	0.1	2.1	3.8	7.7	99.7
'kaolin de Tong-hang'	49.0	33.7	-.-	2.7	0.1	0.45	2.5	0.6	11.3	100.4
Efremov[c]										
Sintszy kaolin	50.0	36.2	0.12	0.7	0.5	0.15	(KNaO 1.15)		11.3	99.0
Minsa kaolin	51.0	34.9	0.08	0.6	Traces	0.2	1.2	3.2	9.23	100.5

[a] Ebelman & Salvetat (1851), pp. 262–3.
[b] Vogt (1900), p. 538.
[c] Efremov (1956), p. 489.

Table 45 *Body analyses of Yuan dynasty underglaze-blue decorated porcelains*[a]

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	Total
Yuan underglaze-blue body	74.9	19.5	0.07	0.2	0.9	0.2	3.0	2.4	-.-	101.2
Yuan underglaze-blue body	74.6	18.7	0.2	1.2	0.3	0.2	2.8	2.4	0.06	100.5
Yuan underglaze-blue body	75.0	19.5	-.-	0.8	0.04	0.2	2.7	2.3	0.02	100.6

[a] Chen Yaocheng *et al.* (1986), p. 123.

This combination of high soda levels with relatively high iron levels often caused +14th-century Ching-te-chen porcelains to reoxidise to warm rusty colours where the clays were exposed and unglazed, particularly on the backs of large +14th-century blue-and-white dishes. The warmth of this reoxidised porcelain complemented the bluish-white glazes, but the reoxidation effect is only skin-deep and has sometimes been removed by abrasion.

While it is possible to trace the use of some clay-rich, kaolin-like material at Ching-te-chen by analysis, the reasons for its introduction are still ambiguous. One scenario might be that non-kaolinised albitic stones were first exploited in Yuan dynasty *chhing-pai* glazes at Hu-thien, where their fusibility would have been an advantage.[514] Any experiments with the same rocks as a single clay bodies would have been initially unsuccessful, due both to their low plasticities and to their low

[514] Wood (1999), p. 58.

refractoriness. Additions of a clay-rich material would have corrected these shortcomings and perhaps opened the way to a new approach to body construction at Ching-te-chen.

It is also possible to take speculation a stage further, and to see this high-clay addition as having some influence on the creation of the *shu-fu* glaze itself. This rather opaque sugary-white glaze may have been evolved to disguise the less pure porcelains produced by these new clay/porcelain stone mixtures, *shu-fu* bodies being noticeably richer in titania and iron oxide than earlier *chhing-pai* wares.[515] Such speculation suggests a combination of innovation and improvisation for this important phase in Ching-te-chen's history, although the scenario is merely one of a number that could explain the observed facts. But however they were devised and developed, the albitic bodies of Hu-thien were highly successful materials, particularly for the production of the massive later +14th-century wares that are typical of the Hu-thien kilns. Dishes and jars, half a metre or more in diameter or height, became routine productions at Hu-thien, particularly in the later Yuan and very early Ming periods.

After this soda-rich phase, porcelains at Ching-te-chen tended to revert to compositions nearer to pre-Yuan dynasty wares. Nonetheless compositional parallels with the earlier wares may be deceptive. It seems possible that middle-Ming wares also contained moderate quantities of clay, whether as true kaolins, or as some related materials, and in quantities between about 10 and 30%.

Difficulties in interpretation escalate with +15th- and +16th-century Ching-te-chen wares, as it seems likely that micaceous porcelain stone, albitic porcelain stone, kaolinised porcelain stone, albitic kaolin and micaceous kaolin could all have been used in these bodies in some combinations (Table 46). All five materials contain essentially the same minerals, but in different proportions, so extracting likely original recipes from established analyses presents a statistical challenge. Most approaches to this problem have been graphical: Chou and Li plotted fluxes against silica;[516] Pollard and Wood used a ternary diagram that calculated kaolinite, mica and albite as its three poles;[517] and Yap and Hua used a statistical system called principle component analysis.[518] By plotting typical Ching-te-chen raw materials on the resulting diagrams, lines connecting typical Ching-te-chen raw materials often crossed constellations of dots representing real porcelains. Lines that missed those areas represented impossible or unexploited recipes. But where connecting lines passed through clumps of established analyses, the material-mixtures indicated would have been feasible. It must be said that hypothetical matches of materials with real porcelains is not conclusive. But with this proviso in

[515] *Ibid.*, p. 61.
[516] Chou Jen & Li Chia-Chih (1960b), p. 51.
[517] Pollard & Wood (1986), p. 111.
[518] Yap Choon-Teck & Hua Younan (1992), pp. 1490–92.

Table 46 *Ching-te-chen porcelains of the later +15th and +16th centuries*[a]

	Date	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	Total
Blue-and-white	+15th C	75.1	19.5	0.05	0.7	0.2	0.2	3.3	0.8	0.02	99.9
Blue-and-white	+16th C	76.4	17.5	0.06	0.7	0.1	0.2	3.5	1.45	0.02	99.9
Blue-and-white	+16th C	73.4	20.3	0.05	0.7	0.3	0.2	3.4	1.6	0.03	100.0

[a] Analyses from the Research Laboratory for Archaeology and the History of Art, Oxford.

mind, the 'best fit' for the majority of wares of mid Ming dynasty date is the use of kaolinised porcelain stone together with small amounts of non-kaolinised stone and/or low-albite kaolin.[519] A fair number of Ching-te-chen porcelains of Ming dynasty date could also have been made from kaolinised porcelain stone alone.

Towards the end of the Ming dynasty kaolin proportions at Ching-te-chen suddenly rose to about 50% of the mix, an effect that is particularly evident in Thien-Chhi export wares of the third to fifth decades of the +17th century.[520] Kaolin levels of this order were also typical for much porcelain of the earlier Chhing dynasty. In the late +19th century and +20th century kaolin levels at Ching-te-chen tended to fall to the 30–40% range, where they remain today.

The full sequence of this development can be seen in the table below, where changes in body compositions have been represented by lines in the analysis-sets (Table 47).

In summary:

- The first group is thought to represent the sole use of kaolinised porcelain stone.
- The second the introduction of high-albite porcelain stones at Ching-te-chen, with their low clay contents supplemented by moderate clay additions (up to 30% of the mix).
- The third group seems to mark a combined use of micaceous and albitic porcelain stones, mixed with small amounts of white clay or kaolin. Single-material bodies made from kaolinised porcelain stones may also have been used.
- The fourth group is characterised by a sharp rise in alumina levels in the late Ming, when kaolin additions of about 50% became typical of the kiln site. These high kaolin levels continued through the early and middle Chhing dynasty.
- The fifth group (mid +19th to late +20th century) is too small to be representative but shows a much wider range of porcelain stone/kaolin mixtures, and some of the recipes do contain 30–40% kaolin.

[519] Pollard & Wood (1986), p. 111.

[520] Wood (1983), pp. 132–4. The short reign of the Thien-Chhi emperor Hsi Tsung 熹宗 was +1621–27, but Impey (1996) believes that the style lasted until +1649. He writes: 'The reasons they are called Tianqi [Thien-Chhi] must be due to the date of their origin and to the fact that so many of them are so marked, with just the two characters; this of course is no indication of date.' *Ibid.*, p. 62.

Table 47 *Ching-te-chen porcelains from the +10th to the +20th centuries*[a]

	+C.	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	Total
5 Dynasties whiteware	10	79.1	15.9	0.06	0.8	0.6	0.3	2.7	0.4	0.12	100.0
5 Dynasties whiteware	10	78.8	16.0	0.03	0.6	0.6	0.2	3.0	0.6	0.13	100.0
Chhing-pai	12	72.9	21.4	0.1	1.2	0.1	0.1	4.0	0.1	0.01	99.9
Chhing-pai from Nan-shih-chieh	12	80.6	15.3	0.03	0.5	0.5	0.2	2.6	0.2	0.08	100.0
Chhing-pai from Nan-shih-chieh	12	79.0	16.1	0.03	0.6	0.6	0.2	2.8	0.6	0.05	100.0
Whiteware from Hu-thien	13	77.0	18.3	0.06	0.75	0.4	0.3	3.0	0.2	0.04	100.1
shu-fu from Hu-thien	14	72.7	20.7	0.2	1.2	0.1	0.2	2.7	2.4	0.07	100.3
shu-fu from Hu-thien	14	73.75	19.5	0.2	1.4	0.2	0.2	3.2	2.0	0.08	100.5
Blue-and-white	14	73.8	19.8	0.1	0.9	0.1	0.1	2.7	2.45	0.04	100.0
Blue-and-white	14	76.7	17.7	0.1	1.0	0.15	0.15	2.05	2.2	0.06	100.1
Red-and-white	14	76.8	17.0	0.05	0.7	0.5	0.2	3.2	1.6	0.03	100.1
Blue-and-white	15	75.1	19.6	0.05	0.7	0.2	0.2	3.4	0.8	0.02	100.1
Chia-Ching period blue and White	16	76.4	17.5	0.06	0.7	0.1	0.2	3.5	1.45	0.02	99.9
Blue-and-white	16	73.4	20.3	0.05	0.7	0.3	0.2	3.4	1.6	0.03	100.0
Khang-Hsi period yellow monochrome	17	67.2	26.5	0.05	0.9	0.35	0.1	3.25	1.6	0.07	100.0
Khang-Hsi period *famille verte*	17	64.7	28.35	0.10	0.95	0.5	0.1	2.8	2.4	0.09	100.0
Khang-Hsi period red-and- white	18	69.9	24.05	0.05	0.7	0.25	0.11	2.8	2.1	0.06	100.0
Red and gold *c.* +1800	19	66.6	25.5	0.06	1.25	0.8	0.15	3.5	2.0	0.09	100.0
Yellow monochrome +19th century	19	67.0	26.2	0.10	1.0	0.4	0.15	3.8	1.3	0.05	100.0
Blue-and-white	20	73.5	20.0	0.05	0.8	0.23	0.15	3.6	1.7	0.05	100.0
Yellow, Hsüan-Thung period, +20th century	20	68.9	24.6	0.1	0.95	0.4	0.1	2.7	2.1	0.08	100.1

[a] Analyses from the Research Laboratory for Archaeology and the History of Art, Oxford.

The Nature and Preparation of Kaolin

True south Chinese kaolin is a 'primary' or 'residual' clay that has been washed by clay-miners or clay-processors from the weathered rock with which it was still associated. With the establishment of an imperial bureau in +1278 in the Yuan dynasty, came the first mention of raw materials specifically for making imperial ware. This '*yü-thu*' 御土 or 'imperial clay' came from deposits that were sealed after use and prohibited for private manufacture. *Yü-thu* was mentioned by Khung Chhi 孔齊 (+1363) as coming from Jao-chou 饒州 and

being powdery white and reserved for imperial use only. He also reminisced:[521]

Present wares are not fine enough . . . when I was at home cousin Shen Tzu-Chheng 沈子成 returned from Yü-kan prefecture 余干州 [in Chiangsi] with two meat dishes, said to have been made 30 years ago in the imperial clay kiln [*yü-thu yao* 御土窯].

Textual research has established that Khung was referring to a period prior to +1322, and has identified 'imperial clay' as coming from mines at Ma-tshang 麻倉.[522]

Thao Chi noted that raw materials came from sources nearby, clay for fine ware from Chin-kheng 進坑, with second-quality materials from Hu-kheng 湖坑, Ling-pei 嶺背 and Chieh-thien 界田.[523] Clay and red rock from Jen-kheng 壬坑 (probably present-day Yin-kheng 銀坑), Kao-sha 高砂 and Tzhu-shih-thang 磁石堂 was only fit for making saggers and moulds.[524]

'Imperial clay' was called 'official clay' (*kuan-thu* 官土) in Ming texts, and the Ma-tshang mines were often mentioned. In *Chiangsi Sheng Ta Chih* (+1597) the sources of 'sandy clay' (*sha-thu* 砂土) were located thus:[525]

Pottery clay for official wares (*kuan-thu*) comes from Ma-tshang mountain 麻倉山 in Hsin-cheng-tu 新正都 . . . the clay has blue-black seams [i.e. carbonaceous material] and spots like grains of sugar [i.e. quartz], as translucent as white jade and with golden spots like stars [i.e. mica].

Archaeological investigation of Hsin-cheng-tu (situated north-east of Kao-ling, 55 kilometres north-east of Ching-te-chen[526]) found evidence of ancient quarrying and piles of leftover clay samples. Analysis of clay from the site revealed Ma-tshang clay to be identical to kaolin, and caused contemporary Ching-te-chen scholar Liu Hsin-Yüan 劉新園 to postulate that Ma-tshang was used as a source of porcelain clay from the Sung dynasty to the Wan-Li reign period. After +1583, when deposits at Ma-tshang were exhausted, Kao-ling became the principal source of porcelain clay, its name appearing as a description of porcelain only during the Chhing dynasty.[527]

John Addis visited Kao-ling in the late +1970s and described the acres of white quartz sand and mica washed out from the kaolinised rock as appearing 'like a very expensive Mediterranean beach'.[528] The original Kao-ling mine, a series of interconnected underground tunnels, was at its most active the late Ming and early

[521] *Chih Cheng Chih Chi*, ch. 2, p. 41, ch. 4, p. 35.
[522] Liu Hsin-Yüan & Pai Khun (1982), pp. 153–4.
[523] A recent study has proved that Chieh-thien, a kind of coarse-grained kaolin, was the same material as Ma-tshang clay 麻倉土 mentioned by later texts, see Feng Yunlong (1995), pp. 295–301.
[524] *Thao Chi* reproduced in Pai Khun (1981), pp. 40–1.
[525] *Chiangsi Sheng Ta Chih*, ch. 7, pp. 4a–b.
[526] For maps see Liu Hsin-Yüan & Pai Khun (1982), p. 156.
[527] *Ibid.*, pp. 152–6.
[528] Addis (1983), p. 63.

Chhing period but closed in +1969.[529] Nonetheless it is still possible to study the preparation of kaolin by semi-traditional means some 40 kilometres north of Ching-te-chen in Anhui province, the area famed for its superior porcelain stone (see p. 514). Kaolin is nowadays processed beside the main road that runs from Ching-te-chen to Huang-shan 黃山 (and Thun-hsi 屯溪). In this mountainous district of southern Anhui heavily kaolinised granite is crushed by trip hammers, stirred with water in tanks, and the high clay content of the rock extracted by froth flotation. Today, small diesel engines turn the heavy pegged beams that trip the hammers, and the clay-water suspensions are stiffened in large cloth-lined presses.[530] The yellowish kaolin processed at these sites does not feel particularly workable, a point made by Vogt when he noted that Ching-te-chen kaolins were 'far from being as white and as plastic as the best European kaolins'. Efremov found some examples of prepared porcelain stone, such as Nan-khang stone, to be more plastic than kaolin, and also mentions the poor plasticity of the Chinese material. Chemical analyses of Ching-te-chen kaolins show rather high iron contents compared with European kaolins, and occasionally high alkali (K_2O+Na_2O) levels from residual micas and feldspars.

Mineralogical analysis of modern Ching-te-chen kaolin has demonstrated that the prepared material is a mixture of kaolinite, halloysite and illite, with halloysite the dominant mineral.[531] Halloysite has a composition similar to kaolinite, but with more water of crystallisation and a crystal structure that is more fibrous than platy, often appearing in a hollow-rolled form.[532] One curiosity of kaolin in southern China is that the use of the material seems largely confined to Ching-te-chen. At Te-hua and other south Chinese porcelain kilns in Fukien and Kuangtung provinces, kaolin usage was either minimal or absent. In Japan too the use of kaolinised porcelain stones, unmixed with refined kaolin, tended to be the norm, as it was too in Korea's porcelain history.

WHY KAOLIN?

Given that so many East Asian porcelain traditions have flourished without kaolin, what advantages did the Ching-te-chen potters gain by introducing the material? This problem has exercised many researchers into Ching-te-chen's practical

[529] Addis writes: 'The top quality kaolin, for some unexplained reason, was called *hou-you* [*hou-yu*, 猴油], monkey oil. There were said to be about twenty openings to these underground workings along the hillside, and following a flagged path we passed several of them, each about three feet in diameter . . . From one opening a chill blast emerged into the sultry August afternoon.' *Ibid.*, p. 64.

[530] Observation of one of the authors (NW) in +1995. These Anhui presses were not quite the same as filter presses in the Western sense, where slip is pumped by pressure into heavy canvas bags placed between stout cast-iron plates, thereby forcing water through the cloth and leaving the plastic clay behind. In the Chinese system a series of stout bags already containing slip are physically squeezed within a horizontal screw press, forcing excess water through the cloth. The dewatering effect is similar, but no slip-pump is used.

[531] See Keller *et al.* (1980), pp. 97–103; Murray (1980), p. 921.

[532] Singer & Singer (1963), p. 24, table 2. The fact that the mineral kaolinite ultimately derives its name from *kao-ling*, but *kao-ling* often does not contain much kaolinite, has caused some problems to mineral taxonomists. See Keller *et al.* (1980), pp. 101–3, for a full discussion.

history, and a number of theories have been proposed to explain the material's adoption. Guo Yanyi [Kuo Yen-I 郭演儀], for example, writes that:[532]

> the addition of kaolin increased the range of firing temperatures for porcelain, reduced the ratio of deformed pieces, and increased the strength and quality of the body and glaze of the wares.

Guo's remarks concerning ceramic strength, resistance to distortion and material quality are certainly valid for later Ching-te-chen wares (late Ming to early Chhing dynasties), where kaolin additions were substantial, and supplied smoother (lower-quartz) and tougher (highly mullitised) porcelains. We have first-hand accounts from Père d'Entrecolles that show how high-kaolin bodies containing half kaolin and half porcelain stone were set in the hottest parts of the large single-chambered *chi-tan hsing yao* 雞蛋形窯 (egg-shaped) kilns (the kiln is discussed in Part 3). Lower kaolin mixtures were placed in the cooler areas of the kiln. Modern measurements within a similarly-shaped Ching-te-chen wood-fired kiln show a temperature range from about Seger Cone 11 to Seger Cone 1 (1,340–1,125°C). This range operated at the height of firing across the eighteen-metre internal length of the particular egg-shaped kiln tested, as the full heat from the firebox fell away towards the chimney.[534] Numerous kaolin-porcelain stone blends were used at Ching-te-chen to accommodate these differences, and glaze recipes were also matched to the different temperature zones. Bending strength experiments on fired high-kaolin porcelains show their superior fired strengths, compared with lower kaolin bodies, an effect probably caused by their high clay contents' converting to the fibrous mineral mullite during firing. The mullite also supplied good resistance to distortion at high temperatures, as the porcelain became 'pyroplastic' in the kiln.[535] These undoubted benefits from kaolin would have been less evident in the Yuan dynasty, when additions of kaolin seem only to have raised the clay contents of the bodies to a minor degree, if at all.[536] In this period extra clay from kaolin simply compensated for the lack of clay in the non-kaolinised, high-albite stones that constituted most of the bodies.

Guo cites the tendency of earlier Ching-te-chen *chhing-pai* wares, apparently made from porcelain stone alone, to distort in firing. However it has been proposed that this effect may have owed more to the way that lime glazes (as used on *chhing-pai* wares) penetrate thin porcelains, and soften their structures at full heat, rather than to the inferior quality of the *chhing-pai* body-material itself.[537] The later low-lime *shu-fu* glazes, applied to rather thickly thrown porcelain stone/kaolin mixtures, were

[532] Guo Yanyi (1987), p. 8.

[534] Efremov (1956), pp. 31, 492. Seger Cones are designed for a temperature rise of 150°C/hr. at the end of the firing. This is faster than the egg-shaped kilns would have fired, so lower equivalent temperatures (for example, 1,320–1,100°C) might represent this range more accurately as, to some extent, time can be traded against temperature in ceramic transformation.

[535] Chou Jen & Li Chia-Chih (1960b), p. 56.

[536] Wood (1983), pp. 132–3.

[537] Wood (1999), p. 61. Parmelee (1948), p. 152, writes: 'Glazes containing alkalies and calcia, with the latter predominating, are more transparent and less viscous, therefore penetrating and reacting more completely with the body.'

less aggressive to the clays' structures at high temperature, and therefore less likely to distort the wares. Tite *et al.* decided that Yuan dynasty albitic porcelains from Ching-te-chen were actually more flux-rich (and therefore less refractory) than Sung dynasty wares and that the main benefit from the change of body-materials was an increase in plasticity and 'green' (unfired) strength.[538] This assessment was made by comparing the combined calculated kaolinite and sericite contents of pre-Yuan dynasty porcelains. This gave an average difference of about 9% in favour of Yuan dynasty wares.

Plasticity, however, is a notoriously difficult aspect of clay's nature to assess from fired chemistry. In addition to the levels of platy minerals present, there are also more subtle influences on workability and green strength. These comprise the average sizes of the platy crystals, the presence or absence of super-plastic clay minerals such as the smectites, and the pH of the prepared pastes. All these factors may make substantial differences to the behaviours of raw materials.[539] It may be significant that Efremov found the breaking strength of dry Nan-khang stone to be six to seven times that of kaolin dried under the same conditions,[540] while Nikulina and Taraeva found Nan-khang stone to have three times the dry strength of San-pao-pheng stone.[541] Green strength is very closely related to plasticity. If the material *were* added to poorly plastic albitic porcelain stone, then it would suggest that +14th-century Hu-thien porcelains were substantially less plastic than the kaolinised-porcelain stone bodies they replaced.[542]

Whatever the reality of the situation, one important practical effect of body changes in the Yuan dynasty must have been that substantial reserves of non-kaolinised (and fairly non-plastic) porcelain stones could be exploited, at a time when production at the kiln-complex was gaining momentum. It may be that a temporary shortage of locally available kaolinised rock prompted some experiment with alternative materials. Resource depletion is cited by Tite, Freestone and Bimson as a likely reason for kaolin's introduction at Ching-te-chen.[543] In Ching-te-chen's later years (i.e. late Ming dynasty to the present day), kaolin proved indispensable for controlling both the varied maturing temperatures and the fired qualities of its vast porcelain output. But for the first few centuries of its use, the purpose and role of kaolin (or its early high-clay equivalent) at Ching-te-chen remains difficult to assess.

[538] Tite *et al.* (1984), pp. 149–50.
[539] Singer & Singer (1963), p. 62.
[540] Efremov (1956), p. 30.
[541] Nikulina & Taraeva (1959), p. 459.
[542] The marked increase in scale seen in some *shu-fu* and many underglaze-blue wares from Hu-thien may suggest an improved plasticity in the porcelain material used. Large open dishes need very little plasticity in making, however, and large Yuan dynasty jars from Ching-te-chen show evidence of having been made in as many as four separate stacked pieces which were then joined with slip, dried somewhat, and turned smooth. This means that the sheer scale of the objects made at Hu-thien in the Yuan dynasty does not necessarily mean that improved plasticity was achieved in the local porcelain paste. See Wood (2000a), pp. 28–9, for discussion.
[543] Tite *et al.* (1984), p. 153.

OTHER NOTABLE SOUTHERN WARES

TE-HUA 德化 PORCELAIN

The problematic role of kaolin is particularly evident when the technological history of another successful south Chinese porcelain centre is considered, that of Te-hua in Fukien province. This kiln-complex is sited some 600 kilometres south-east of Ching-te-chen in a mountainous area of southern Fukien province. Numerous porcelain kilns operated in and around the county town of Te-hua and porcelain stone seems to have been the main raw material throughout the history of this kiln-complex, which has been in continuous production since the +10th century.

The raw materials from the Te-hua area are often superior to those used at Ching-te-chen, but the district lacked Ching-te-chen's exceptional lines of communication, *via* the Chhang river 昌江 to the Pho-yang lake 鄱陽湖 and into the Yangtze river, and southwards along the Kan river 干水 towards Canton. Consequently Te-hua has always been a somewhat isolated manufacturing centre, although its reputation as a producer of white porcelain in south China is second only to Ching-te-chen's.

We have known for many years that porcelain of the *chhing-pai* type was made from the Northern Sung dynasty onwards, at kilns in the town of Te-hua and surrounding areas.[544] Recent excavation has clarified the location and sequence of kilns making *chhing-pai* porcelain, and has unearthed a significant whiteware that acted as an intermediary between *chhing-pai* and later 'Blanc de Chine'. The ceramic type for which the Te-hua kilns came to be most famous was not made till the mid Ming dynasty, when refinement of body and glaze led to the manufacture of lustrous whitewares, later known in Europe as 'Blanc de Chine' and in China as 'pork-grease white' (*chu-yu pai* 豬油白) or 'ivory white' (*hsiang-ya pai* 象牙白).

The peak of production of Blanc de Chine has been judged to be the +16th to +17th centuries. *Thien Kung Khai Wu* (The Exploitation of the Works of Nature, +1637), notes that fine clay came from Yung-ting 永定.[545] Materials were mined from local deposits, Te-hua wares being made from porcelain stone alone or with very small additions of clay. The porcelain stone was crushed with water-wheels in the same manner as Ching-te-chen, then purified and levigated in tanks of water. *Chhüan Nan Tsa Chih* (+1604) notes that clay was dug from shafts in the side of hills and was then refined through levigation and filtration.[546] Wares were fired in stepped, chambered kilns built up hillsides. Firings of the high-temperature kilns were expensive, and a +20th-century text informs us that they were generally shared between several families.

[544] See Kerr (2002).

[545] *Thien Kung Khai Wu*, ch. 7, p. 5b. Yung-ting is about 175 kilometres south-west of Te-hua.

[546] *Chhüan Nan Tsa Chih*, p. 3a. Donnelly (1969), pp. 20–1, reproduces this text in an edition printed before +1620, p. 297. He also investigates various Chinese textual references in his appendix 1, pp. 293–301.



Fig. 50 Digging for clay at Te-hua, +1936

It is likely that the same practice obtained in earlier times. Wealthier clans would fill two or three separate chambers with pieces, while poorer potters' families would only have the use of a single chamber.[547] Te-hua workshops turned out a variety of vessels, many for use in temples and tombs. The best-known merchandise was porcelain figures, mainly of Buddhist deities, and many of the finest pieces were subsequently exported.

[547] Wang Tiao-Hsing (1936), p. 7.

Table 48 *Te-hua potter families active in the early +20th century*

Village	Clan name	Number of kilns
Pao-mei-hsiang 寶美鄉	Mainly Su 蘇	10
Tung-thou-tshun 東頭村	Cheng 鄭	7
Kao-yang-tshun 高陽村	Chhen 陳	10
Nan-ling-tshun 南嶺村	Yen 顏	6
Huang-tzhu-tshun 黃祠村	Ho 何	4
Le-thao-tshun 樂陶村	Sun 孫, Chhen 陳	7
Hou-so-tshun 后所村	Chhen 陳, Lin 林	7
Ting-kan-tshun 丁墘村	Chhen 陳	1

Te-hua was one of the few production centres where potters signed their names. Another such was I-hsing 宜興, whose red stonewares were sought after by connoisseurs for whom signed products gave enhanced value. Te-hua was a different case. Teapots, cups, vases and figurines were made for a largely local market within China, and used in the home, local temples, domestic shrines or tombs. They were neither popular with connoisseurs, nor written about in glowing terms in the Ming dynasty. Indeed, the author of *Thien Kung Khai Wu* opined that Te-hua 'specialised in making porcelain Buddhas and delicate figurines of no great practical value'.[348] The broader tastes of the Chhing dynasty allowed one commentator to give grudging praise, commenting that most Te-hua was very thick-bodied but some of the Buddha figurines were especially refined.[349]

Te-hua porcelain was exported, and many export pieces were signed by their makers. Certain family names were prominent in the industry: Ho 何, Chhen 陳, Yen 顏 and Su 蘇 were especially common. In +1936, an industry handbook noted eight villages in the Te-hua area engaged in workshop manufacture, with different clans active in each locality (Table 48).[350]

Tradition states that one of the earliest potters to be associated with the region was Yen Hua-Tshai 顏化彩 (+864 to +933), who worked as a potter under the tutelage of an uncle who was foreman of a factory at Ssu-pin 泗濱, an area where large kiln waster heaps record former activity. Most Te-hua potters' names, however, are associated with the period of greatest skill and achievement in the late Ming to early Chhing dynasty. Te-hua's most renowned potter was Ho Chhao-Tsung 何朝宗, whose works are represented in collections around the world. Ho's family is said to have moved to Fukien from Chiangsi province in the Hung-Wu reign period, his ancestor being employed in militia deployed to combat coastal raids. The family settled at Lung-thai-tshun 隆泰村 in +1384, a hamlet at the centre of the later Ming

[348] *Thien Kung Khai Wu*, ch. 7, p. 5b.
[349] *Ching-te-chen Thao Lu*, ch. 7, p. 6b.
[350] Wang Tiao-Hsing (1936), p. 2.

dynasty pottery industry.[551] He was first mentioned in *Chhüan-chou Fu Chih* (Local Gazetteer of Chhüan-chou, +1612), and although little is known about his career some Chinese scholars believe him to have been active sometime between +1522 and +1612.[552] He started by making clay images for temples, and later graduated to white porcelain. A disciple and relative of Ho Chhao-Tsung, Ho Chhao-Chhun 何朝春, followed in his master's footsteps in creating votive images. Many were exported to Europe in the +17th century.[553]

It is said that Tseng Mao-Tu 曾茂篤 and Tseng Ta-Chhü 曾達衢 also came from Lung-thai-tshun and were active in the Chia-Ching reign period. Their specialism was the use of overglaze enamels to decorated Blanc de Chine. Yen Pang-Tso 顏邦佐 (+1675–1735) was apprenticed to the pottery industry as a child, and being a good businessman as well as a good potter, was instrumental in building halls of worship as well as providing them with ceramic artefacts. The brothers Su Ming-Yü 蘇明裕 (+1704–57) and Su Chhung-Kuang 蘇重光 (+1708–58) set up the Wei-khu kiln 尾庫窯 and manufactured products with brand names that sold well in the markets of Te-hua and Chhüan-chou 泉洲, both to domestic buyers and for export. Yen Chia-Yu 顏嘉猷 (+1777–1844), another native of Ssu-pin, worked all his life in the pottery business but was also a traveller, accompanying ships with cargoes of tea and ceramics to Canton, Taiwan and Vietnam. Yen Chung-Shan 顏中山 (+1849–1908) went to Taiwan and made his second home there, selling Te-hua ceramics and helping Chinese settlers to repatriate corpses for burial on the mainland. Commercial and familial links with Taiwan remained strong in the late +19th and +20th centuries, when the industry went through periods of both growth and decline. The names of many more potters and writers connected with Te-hua are known, prominent among them Su Hsüeh-Chin 蘇學金 (+1869–1919), Yen Chhing-Chhuan 顏晴川 (+1874–1920), Hsü Yu-I 許友義 (+1887–1940), Hsü Chhi-Chung 徐其中 (+1904–73), Su Chhin-Ming 蘇勤明 (+1910–69) and Chhen Chhi-Chang 陳其章 (+1914–83).[554] Many Te-hua figures were made for overseas customers in the +20th century. Biggest clients include Taiwan, Japan, Malaysia, Singapore and Hong Kong. Descendants of Hsü Yu-I live in Hong Kong and manage a ceramic factory there.[555]

The potters of Te-hua had their own patron deity, as workers at other kilns did (see pp. 166–7, 206 and 566–7). His name was Lin Ping 林炳 and, in common with most potters' saints, he was himself a potter. He worked in the early Northern Sung period, but his small, square kiln was inefficient and could not satisfy market demand. In a dream a goddess called Lady Chin 金夫人 advised Lin how to build

[551] Hsü Pen-Chang (1993), pp. 1–8.

[552] Zeng Fan (1997a), p. 26. See also Donnelly (1969), pp. 270–6, 309. Ayers questions this view and the nature of historical documents detailing Ho's career, believing that Ho 'worked during the second decade of the seventeenth century'. Ayers (2002), p. 28.

[553] Hsü Pen-Chang (1993), pp. 1–8. See also Donnelly (1969), pp. 276–7.

[554] *Ibid.*, pp. 13, 25, 28–30, 32, 37–53. For information on Su Hsüeh-Chin and Hsü Yu-I, see also Zeng Fan (1997a), p. 26.

[555] *Ibid.*, pp. 26–7.

a new type of kiln in the shape of her womanly body, with a large rounded dome in the middle (the belly) and two smaller domes on each side (the breasts). The first successful prototype new kiln, afterwards copied all around Te-hua, was constructed in +1094.[556]

TE-HUA PRODUCTION

Porcelain stone without significant kaolin additions appear to have been the basis for Te-hua's production for most of its history, and any changes that have occurred in these raw materials have been small and largely chronological, with the wares becoming whiter and more translucent as the centuries passed.[557] These improvements in the fired qualities of Te-hua porcelain were probably achieved at the expense of plasticity, as progressively less kaolinised rocks were exploited by the Te-hua potters (Table 49).

Two technical features above all have characterised the Te-hua raw materials through their history, namely an unusually low level of iron and an unusually high level of potassium oxide. The first accounts for the unusual whiteness of the material and the second for its translucency. These features are evident in the early wares, but they became increasingly important from the +15th century onwards. In the later Ming and Chhing dynasties the quality of Te-hua porcelain could approach that of opal glass or translucent white marble, with a remarkable integration of glaze and clay that can give the illusion of a single translucent material, rather than a white porcelain with a separately glazed surface.

The potassium oxide content (up to 6.8%) of Te-hua porcelain that is responsible for this unusual translucency is often so high that it cannot be explained by potassium mica alone, and represents the presence in the original rocks of another potassium source, such as potassium feldspar. Nonetheless the Te-hua material is not a feldspathic porcelain in the strict sense, as its feldspar content is secondary to its content of hydro-mica. During firing the hydro-mica serves as the porcelain's main body-flux, and also provides the prime source of plasticity in making.[558]

TE-HUA PORCELAIN CLAY

Two types of porcelain clay have been studied at Te-hua, one a well-kaolinised example and the other a much less altered material.[559] Ssu-pan porcelain clay 四班瓷土 is of the first type and consists mainly of quartz and hydro-mica, together with some primary kaolinite. Ssu-pan-like materials seem typical of Te-hua's earlier phase, when thrown and pressed *chhing-pai*-type wares were the main productions. The throwing style of these wares suggests the use of a relatively plastic material, an

[556] The story is related in full by Yuan Bingling (2002), p. 44.
[557] Guo Yanyi & Li Guozhen (1986), pp. 141–7; Li Chia-Chih (1998), pp. 350–63.
[558] Guo Yanyi & Li Guozhen (1986), p. 145.
[559] *Ibid.* Li Chia-Chih (1998), p. 353.

Table 49 *Te-hua porcelain bodies, Sung to Chhing dynasties*[a]

	Kiln site	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	P_2O_5	Total
Te-hua, Northern Sung dynasty	Kai-te	71.7	21.8	-.-.	0.6	0.3	0.2	5.2	0.08	0.03	99.9
Te-hua, Northern Sung dynasty	Kai-te	77.5	17.7	0.04	0.55	0.09	0.06	4.6	0.1	0.02	100.7
Te-hua, Southern Sung dynasty	Kai-te	81.6	14.9	0.09	0.9	0.1	0.1	2.9	0.08	-.-.	100.7
Te-hua, Yuan dynasty	Chhü-tou-kung	77.8	18.5	0.03	0.4	0.2	0.2	4.45	0.10	0.03	101.7
Te-hua, Ming dynasty	Tsu-lung-kung	76.4	17.4	0.08	0.3	0.04	0.06	5.7	0.10	0.03	100.1
Te-hua, Ming dynasty	Tsu-lung-kung	76.7	16.8	0.10	0.35	0.15	0.08	5.9	0.1	0.03	100.2
Te-hua, Chhing dynasty	Chhü-tou-kung	75.6	17.3	0.1	0.2	0.04	0.10	6.5	0.1	0.02	100.0

[a] Guo Yanyi & Li Guozhen (1986), p. 143; Li Chia-Chih (1998), p. 355.



Fig. 51 Carrying basket-loads of clay at Te-hua, +1936

effect particularly evident in the tall vases with indented trumpet-shaped mouths, produced at the Chhü-tou-kung kilns 屈斗宮窯 near Te-hua town.[560]

The second material, Pao-mei porcelain clay 褒美瓷土, is much richer in potassium oxide and contains some unaltered potassium feldspar. It seems closer to the

[560] Anon. (1990c), p. 92.

Table 50 *Te-hua porcelain stones*[a]

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	P_2O_5	Ig. loss	Total
Ssu-pan stone rock (raw)	75.9	15.3	0.1	0.6	0.04	0.05	2.5	0.05	trace	4.85	99.4
Ssu-pan rock (fired)	80.2	16.2	0.1	0.7	0.04	0.05	2.65	0.05	trace		100.0
Pao-mei rock (raw)	78.6	12.95	0.09	0.3	0.1	0.1	5.9	0.2	trace	2.3	100.5
Pao-mei rock (fired)	80.0	13.2	0.1	0.3	0.1	0.1	6.0	0.2	trace		100.0

[a] Guo Yanyi & Li Guozhen (1986), p. 145, table 3.

types of porcelain stone used at Te-hua from the Ming dynasty to the present day and its clay content must have been minimal or entirely absent. This would have made the material very low in plasticity and more suitable for moulding than for throwing. Moulding by pressing the porcelain material into hollow piece-moulds was certainly the favoured making technique at Te-hua over this period.

The analyses above are of the raw rocks rather of than of the crushed stones prepared for making. Neither corresponds exactly to any individual analysis that has been published for Te-hua ware, perhaps because alumina levels in the rocks became enhanced during the materials' preparation, or because the porcelain stones examined were somewhat atypical (Table 50).

TE-HUA GLAZES

Early Te-hua porcelain of the Sung and Yuan dynasties is regarded as a type of *chhing-pai* ware because of its transparent, blue-tinged glaze, and its carved and, later, moulded decoration. However, early Te-hua glazes are somewhat lower in lime than those used at Ching-te-chen, making the Te-hua glazes more 'unctuous' and less icy in their surface qualities. Te-hua potters also experimented with low-lime semi-opaque 'snow white' glazes of the *shu-fu* type as early as the Northern Sung dynasty, thus anticipating the Ching-te-chen *shu-fu* glazes by some 200 years. Te-hua *chhing-pai* pieces tend to be larger than contemporary Ching-te-chen porcelains, particularly in the Southern Sung dynasty when dishes some 30 centimetres in diameter were commonplace. This ability to make wide dishes safely at Te-hua may have owed something to the use of lower-lime glazes, as these would have been less aggressive to the porcelain bodies at peak temperatures. Apart from slightly lower levels of iron oxide, early Te-hua *chhing-pai* bodies are directly comparable with contemporary Ching-te-chen *chhing-pai* wares, so differences in body-materials do not seem to explain their greater resistance to distortion in the kilns (Table 51).

Table 51 *Northern and Southern Sung dynasty Ching-te-chen and Te-hua* chhing-pai *porcelain bodies compared*

		SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	P_2O_5	Total
Five Dynasties	Ching-te-chen[a]	75.8	18.3	0.2	1.0	0.7	0.8	2.4	0.4	-.-.	100
Northern Sung	Ching-te-chen[b]	75.6	19.35	0.06	0.5	0.4	0.2	3.7	0.15	-.-.	100
Northern Sung	Te-hua, Kai-te[c]	77.5	17.7	0.12	0.6	0.09	0.06	4.58	0.12	0.02	101
Southern Sung	Te-hua, Kai-te[d]	77.8	18.5	0.03	0.4	0.17	0.17	4.45	0.10	0.03	102

[a] Chou Jen & Li Chia-Chih (1960a), Table 1, p. 53.
[b] Analyses from the Research Laboratory for Archaeology and the History of Art, Oxford.
[c] Guo Yanyi & Li Guozhen (1986), table 1, p. 143.
[d] *Ibid.*

OXIDATION AND TRANSLUCENCY

One important advantage of the lower iron oxide levels supplied by the Te-hua porcelain stones was that many (if not most) of its wares could be fired in oxidation. This gave a pale ivory colour to the porcelain, rather than the stronger straw colours typical of oxidised Ching-te-chen wares. *Thao Chi* states that accidentally oxidised Ching-te-chen *chhing-pai* wares were held in low regard in the area where they were made, and sold at a discount to markets beyond Chiangsi province.[561] Oxidation firings were occasionally practised at Ching-te-chen, but at Te-hua oxidation was the rule rather than the exception. These clear oxygen-rich firings give some Te-hua porcelains a superficial similarity to Ting wares, although analysis shows the Te-hua and Ting materials to be at polar opposites, in terms of their of porcelain composition (see Tables 23 and 49), being unusually quartz-rich and clay-rich, respectively.

One of the most interesting technical features of Te-hua porcelain is the pronounced translucency achieved in many Ming and Chhing dynasty wares. This effect is most marked in Te-hua specialities such as cups made in the style of carved rhinoceros-horn, and in some small Te-hua stemmed bowls; in both cases liquid can be plainly seen through the porcelains' translucent walls. Translucency in porcelain is achieved through the generation of large amounts of glass and by a concomitant decrease in porosity in the body during firing. High levels of body-glass can also cause the sudden collapse of the wares at the kilns' finishing temperatures.

That collapse was generally avoided in Te-hua porcelain wares seems to have been due to a combination of factors. The first was the high-potassia and the low-soda contents of the local porcelain stones. The potassia derived from the natural mixture of hydro-mica and potash feldspar in the raw materials, both of which melt into extremely viscous glasses at temperatures above 1,200°C. During firing the mica forms an incongruent mixture of mullite, corundum and glass[562] while potash

[561] *Thao Chi* in Pai Khun (1981), p. 40.
[562] Sundius in Sundius & Steger (1963), p. 385.

feldspar forms a mixture of leucite and glass that shows unusual viscosity.[563] As firing temperatures increase more body-quartz is attacked and dissolved by these potassic glasses, which further raises the glasses' viscosity and delays high-temperature collapse of the wares. The second was the use of low-lime glazes, which was a practice very characteristic of Te-hua wares in the Ming and Chhing dynasties. Such glazes helped control firing distortion by interacting far less with the bodies of the wares. Nonetheless, there is a limit to how long these various effects can postpone overfiring and eventually the porcelains softens and slumps and forms a fused and molten mass within the kiln.

Good temperature control was therefore vital for wares that were taken so near to their firing limits and this need for even and consistent firings benefited from local improvements to the dragon kiln principle. These are evident as early as the Southern Sung dynasty at the giant climbing kiln at Chhü-tou-kung, now within the limits of Te-hua town.[564] The surviving foundations of the Chhü-tou-kung kiln show that it was once divided into a series of seventeen separate chambers, rather than the usual continuous tunnel. This helped to eliminate unevenness in firing by forcing the kiln-gases to follow a roller-coaster path up the kiln's length, with a consequent reduction in flame-speed. As the slower-moving gases filled the firing chambers more even temperatures developed through conduction and radiation. It also became possible to fire each section in turn, allowing proper control of each separate chamber. This early 'chicken cage' design was later refined as the Te-hua 'step kiln'; perhaps the most sophisticated traditional kiln design of southern China (see further discussion in Part 3 of this book).[565]

LUNG-CHHÜAN CELADON WARES 龍泉窯

Excavations at Ching-te-chen have shown that white-firing porcelain materials were found near to kilns that were making greenish ash-glazed stonewares (see p. 201).[566] As the new white-firing materials were exploited and developed, production of the old grey-bodied stonewares was either reduced or abandoned, and the kilns converted to white porcelain manufacture. This replacement of local stoneware traditions by white porcelains became a common pattern in southern China, but an important exception to this principle occurred at the Lung-chhüan kilns in southern Chekiang province. In this case the newly discovered porcelain raw materials were only rarely used to manufacture white porcelains. Their main use was to improve the quality of the local greenwares, a process that, in some cases, involved the deliberate adulteration of the local white porcelain stones with iron-rich clays.[567] This approach resulted in very high-quality celadon wares with smooth, pale-grey bodies that were far closer in their technical

[563] Cardew (1969), pp. 49–50.
[564] The kiln is more than 57 metres in length, see Anon. (1979d), pp. 51–61.
[565] Ye Wencheng (1986), pp. 325–8, especially p. 327.
[566] Liu Xinyuan (1992), p. 35.
[567] Chou Jen *et al.* (1973), p. 141.

natures to the newly developed white porcelains of Ching-te-chen than to any existing southern stonewares of the Yüeh ware type. The Chekiang white porcelain material has been identified in a dated context in the later +10th century (see pp. 674–5 in Part 6), but it became most significant for celadon-making in the early +13th century, when the blending approach with a ferruginous clay became standard practice.

At Lung-chhüan there were better clays than those of Yüeh, abundant timber for fuel, a plentiful water supply and mountain slopes for dragon kilns. Manufacture had started in the area as early as the +3rd century, and products served a local market till the +10th century. From the end of the Northern Sung dynasty there was rapid development, the industry peaking in the Southern Sung and Yuan periods. One critical factor was the improvement in transport to the remote, mountainous area of southern Chekiang in +1091–2, with the dredging of more than 165 local river beds.[568]

Technologically, Lung-chhüan wares continued and improved upon earlier greenware industry in Chekiang province. The use of porcelain raw materials in the Lung-chhüan glazes also improved their qualities by lowering their iron oxide and titania contents, and boosting their levels of potassium oxide. The resulting lime-alkali glazes developed an unctuous jade-like quality in firing, and their lower colourant percentages supplied colours that ranged from duck-egg blue to sea-green.[569] The greater viscosity of these glazes allowed them to be applied from three to eight times the thickness of the older clay-and-ash Yüeh ware glazes, usually in a series of separate coatings.[570] These successive glaze applications were sometimes fixed by a series of low-temperature firings before the final glaze firing to the full heat of the kilns, which was typically 1,220–1,280°C.[571] Northern Sung to mid Southern Sung dynasty pots bore thin glazes applied only once, the glazes having substantial calcium content typical of the high-lime glaze group. Around +1200, court officials who lusted after imperial Kuan wares 官窯 made at Hang-chou (see pp. 264–5) set up their own kilns at Ta-yao 大窯, and at Hsi-khou 溪口. From *c.*+1200–60 those kilns and others developed superior Lung-chhüan ceramics that imitated Kuan ware, some with white body and thick glaze and others with extremely thin black body and multiple layers of glaze. The former was low in alumina, high in silica and very low in iron. The latter was based on iron-rich *tzu-chin* 紫金 clay, could be as thin as 1 millimetre, and had a lower silica content, but a higher alumina and iron content. The glaze layers of 0.5 to 2 millimetres thick, were built up in three to four applications by dipping, pouring or brushing on, or being blown on in a fine spray. A single vessel was glazed and biscuit-fired several times to achieve translucent glazes with the colour and texture of jade. The glazes belonged to the lime-alkali group, and were the finest quality ever made at Lung-chhüan (Table 52).

[568] *Lung-chhüan Hsien Chih*, ch. 12 ('*I-wen Chi-shu*'), p. 7, quoted in Chu Po-Chhien (1993), pp. 14, 35.
[569] Wood (1999), pp. 75–7.
[570] Vandiver & Kingery (1986a), p. 219.
[571] Four layers of glaze can be clearly seen in the magnified cross-section of a Sung dynasty Ta-yao sherd illustrated in Sundius & Steger (1963), p. 430, fig. 30. For suggested firing temperatures for Lung-chhüan celadon wares, see Chou Jen *et al.* (1973), p. 154.

Table 52 *Body and glaze thickness of Southern Sung dynasty white paste and black paste compared*[a]

	Thickness	SiO_2	Al_2O_3	Fe_2O_3	CaO
BODY white paste	3–8 mm	67–33%	19–23%	2–2.4%	
BODY black paste	1–5 mm	58–65%	24–32%	3.36–4.5%	
GLAZE white paste	0.5–2 mm				0.23–0.29%
GLAZE black paste	<1 mm				6.23–16.83%

[a] Li Dejin (1994), pp. 90–2; Chu Po-Chhien (1998), pp. 17–18, 23, 37–8, 43.

Yuan dynasty potting practice favoured only one layer of glaze again, applied over thicker bodies, though the finest wares still bore several glaze applications.[572] Wares of astonishing scale and volume were made, with some vases and dishes approaching a metre in height or diameter. These moulded and thrown wares were also of substantial cross-section and often fired in giant dragon kilns that could contain tens of thousands of vessels in a single setting. This highly productive phase was boosted by a huge export industry.[573] Such massive vessels were made for the needs of Mongol nobles and for export to Islamic patrons in West Asia. In the Ming dynasty Lung-chhüan ceramics became heavy and thick, with rather coarse decoration, though they continued to be exported to West Asia and Africa.[574] Lung-chhüan was active throughout the Ming and Chhing dynasties, but after the mid +14th century was increasingly challenged by Ching-te-chen, where fair copies of Chekiang celadons were made. At the beginning of the Chheng-Hua reign period (+1465–68) an imperial edict ordered a halt in production as a mark of mourning for the previous emperor, but by the succeeding Hung-Chih reign period no more mention was made of Lung-chhüan in imperial documents.[575] The rise of Ching-te-chen blue-and-white porcelain at the end of the +15th century led to the loss of many of Lung-chhüan's more important markets, and the Lung-chhüan kilns declined.

By the Chhing period, a handful of kilns at Ta-yao and Sun-kheng 孫坑 were supplying low-quality ceramics to local clients only. The Sun-kheng kiln, seven kilometres south-west of Lung-chhüan, only started production in the Chhien-Lung reign period.[576] Production in the Lung-chhüan area has only recently been revived.[577]

[572] For example, exquisite wares splashed with iron-brown made for the Japanese market and known there as *tobi seiji* 飛青磁 have great depth of glaze resulting from more than one application.
[573] Krahl (1986), p. 44.
[574] Li Dejin (1994), pp. 90–2; Chu Po-Chhien (1998), pp. 23–4, 26–8, 44–5, 47–8.
[575] Liu Hsin-Yüan (1993), pp. 40–1, 82.
[576] Chu Po-Chhien (1998), pp. 28, 48.
[577] Chou Jen *et al.* (1973), pp. 131–56.

Table 53 *Lung-chhüan raw materials (i): porcelain stones*[a]

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	Total
Low-iron porcelain stones										
Ta-yao china stone (natural)	76.2	19.1	0.3	1.75	0.01	0.2	2.3	0.2	0.02	100.1
Ta-yao china stone (refined)	73.6	20.7	-.-.	1.9	0.4	0.5	2.5	0.5	0.03	100.1
Yüan-ti 源底 china stone (natural)	79.6	15.6	-.-.	1.1	0.7	0.3	1.9	0.7	0.04	99.9
Yüan-ti china stone (refined)	74.2	18.2	-.-.	1.3	0.8	0.3	4.8	0.2	0.05	99.9
Mao-chia-shan 毛家山 china stone (natural)	75.3	19.2	-.-.	0.6	-.-	0.2	4.4	0.2	0.05	100.0
Mao-chia-shan china stone (refined)	68.9	22.8	-.-	0.9	1.2	0.8	5.0	0.4	0.07	100.1

[a] Chou Jen *et al.* (1973), p. 137.

THE TECHNICAL DEVELOPMENT OF LUNG-CHHÜAN CELADON WARE

Our understanding of how the Lung-chhüan kilns grew and developed owes much to a major analytical project on Lung-chhüan celadon production commissioned by the Central Ministry of Light Industry in +1959. Part of this project was a detailed study of Lung-chhüan's history and its raw materials carried out by Chou Jen 周仁, Chang Fu-khang 張福康 and Cheng Yung-fu 鄭永圃, then of the Institute of Silicate Chemistry and Technology 硅酸鹽化學與工學研究所, Shanghai.[578] Chou *et al.*'s study involved an exploration of body and glaze technology, making, setting and firing techniques, and detailed studies of Lung-chhüan kiln design. Wares from the Five Dynasties period to the present day were analysed, and their compositions interpreted in the light of local raw materials. The most important of these materials were the porcelain stones of the Lung-chhüan district, and these were analysed both before and after the usual crushing and washing processes (Table 53).

These Lung-chhüan materials show typical oxide balances of East Asian kaolinised porcelain rocks, namely high-silica, low-titania, average-to-high potassia and low-soda percentages. In general the iron oxide contents of the Lung-chhüan stones are somewhat higher than at Ching-te-chen, and far higher than at Te-hua. How much this difference in iron levels influenced the development of Lung-chhüan as a greenware rather than as a whiteware centre is an interesting problem. It is not

[578] Now the Shanghai Institute of Ceramics 上海硅酸鹽研究所, see Part 7, pp. 794–7.

impossible that the destinies of huge ceramic industries in China turned on differences as small as a few tenths of a per cent of iron oxide in their available raw materials.

On the evidence of the above analyses, the preparation of porcelain stone in the Lung-chhüan district seems to have enhanced the mica content at the expense of quartz, a rather different result from that observed at Ching-te-chen (see Table 39). Stannard speculates as to whether:[579]

> the pulverising practices in the Longquan [Lung-chhüan] District produce a significant amount of clay-mica for flotation from the 20–30% larger grained supply in the parent rock?

What is also noticeable in these analyses is the general rise in the iron oxide contents of the stones after preparation. This too reflects some enhancement of mica in the prepared material, as much of the iron in porcelain stone is associated with hydromica, with the iron replacing some aluminium in the mineral's crystal structure.[580] As Guo Yanyi [Kuo Yen-I] remarks about the Lung-chhüan stone:[581]

> Some of the porcelain stone produced in Zhejiang [Chekiang] province has quite a high iron content which is mostly in the form of ions in the crystalline structure of the sericite. It is technically difficult to wash out and reduce this iron content, and sometimes washing can have the opposite effect and can actually increase the iron content.

In practice, the extra iron in the Lung-chhüan material was a positive advantage to the appearance of the wares. These iron levels were low enough not to detract from the quality of the celadon glazes, but still high enough to cause the Lung-chhüan clays to reoxidise to warm reddish colours where the bodies were free from glaze. The intensity of the effect was encouraged by the finely divided nature of the iron and also by its close association with alkaline ions in the clays. As with Yuan dynasty blue-and-white wares, the warmth of the reoxidised clay served as an excellent foil to the cool colours of the reduced glazes. Indeed, good copies of Lung-chhüan wares were made at Hu-thien near Ching-te-chen in the Yuan dynasty that exploited the underlying similarities between the two materials.[582]

Physical Nature of Lung-chhüan Porcelain Stone

There is a noticeable difference in appearance between Ching-te-chen and Lung-chhüan porcelain stones in their raw states. At Ching-te-chen the material is tough and dense, to the extent that similar stones were used in Russia for making grindstones.[583] At Lung-chhüan, by contrast, the porcelain stones tend to be porous and

[579] Stannard (1986), p. 251.
[580] Wood (1978), p. 105.
[581] Guo Yanyi (1987), p. 5.
[582] Krahl (1986), p. 42.
[583] Efremov (1956), p. 489.

friable, and far easier to crush.[584] Much of Lung-chhüan's massive production consisted of large and thick-bodied celadon wares, so this softer material must have been a boon to the potters. Observation at Ching-te-chen and Te-hua shows that the traditional method for preparing powdered porcelain stone from the very tough local rocks was an effective but not especially rapid process and the more friable material at Lung-chhüan must have allowed more efficient processing of the raw material. Nonetheless a huge supporting rock-crushing industry must have operated in southern Chekiang province, in order to supply the hundreds of tonnes of body and glaze materials regularly consumed by the Lung-chhüan kilns.

Lung-chhüan Red Clays

Chou, Chang and Cheng also studied the red clays that were mixed with the Lung-chhüan porcelain stones, before and after their preparation.[585]

These analyses show the Lung-chhüan red clays to be rather variable materials that, in some cases, change their compositions radically on preparation. This suggests that at least some of the red clays were primary, and that their main losses during crushing and washing were grains of coarse primary quartz. Where these refined and prepared red clays were added to the pale-firing porcelain stones the intention was to raise the iron oxide contents of the bodies from about 1% in the natural stone to about 2–2.4% iron oxide in the prepared clays. With iron oxide levels in the red clays ranging from 3.2 to 15.2% (see Table 54) additions from about 10–30% would have met this need, depending on the iron oxide contents of the clays used.

While most Lung-chhüan celadon bodies seem to have been made from porcelain-stone/red-clay mixtures, a few kiln sites seem to have made some wares from porcelain stone alone, particularly at the premier Southern Sung dynasty kiln-complex at Ta-yao. Ta-yao produced pale bluish-glazed celadon wares of outstanding quality that are known as Ti wares 弟窯 in China and *kinuta* wares 砧窯 in Japan. The development of Ta-yao celadon bodies, from the $+10^{th}$ to the $+15^{th}$ centuries, can be summarised by Table 55.

Northern Sung dynasty wares from this site are paler versions of Yüeh wares from northern Chekiang province, and were probably made from natural stoneware clays (see first analysis). The new porcelain-type materials (remaining analyses) were developed in the Southern Sung dynasty and remained the prime Ta-yao material thereafter.

The general agreement between the iron contents of the local Ta-yao porcelain stone and the $+12^{th}$- to $+14^{th}$-century wares from this kiln site led Chou *et al.* to suggest that red clay was probably not used in the Ta-yao bodies. They also explain the

[584] A view based on examples exhibited at the First International Conference on Ancient Chinese Pottery and Porcelain, Shanghai, +1982.

[585] Chou Jen *et al.* (1973), p. 137.

Table 54 *Lung-chhüan raw materials (ii): red clays*[a]

Sources of red clay	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	Total
Kao-chi-thou 高際頭 red clay (natural)	69.7	18.8	0.5	3.2	1.3	0.5	5.45	0.5	0.1	100.0
Kao-chi-thou red clay (prepared)	62.2	21.5	0.5	4.3	0.7	0.9	4.7	1.1	0.1	96.0
Pao-shih 寶溪 red clay (natural)	63.7	22.1	1.1	6.4	- -	1.0	5.3	0.3	0.1	100.0
Pao-shih red clay (prepared)	50.5	30.75	1.8	10.4	1.2	1.4	3.7	0.2	0.15	100.1
Huang-lien 黃連 red clay (natural)	51.0	27.5	2.2	15.4	0.5	1.0	1.7	0.6	0.2	100.1
Huang-lien red clay (prepared)	50.0	28.6	2.0	15.2	0.2	1.1	2.4	0.5	0.1	100.1
Mu-tai-khou 木岱口 red clay (natural)	73.7	17.1	0.7	3.8	0.15	0.9	3.2	0.4	- -	99.95
Mu-tai-khou red clay (prepared)	63.1	26.6	0.85	5.2	0.2	0.35	3.2	0.4	- -	99.9

[a] Chou Jen *et al.* (1973), p. 137.

Table 55 *Lung-chhüan celadon ware bodies from Ta-yao, Northern Sung dynasty to early Ming dynasty*

Date	Kiln site	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	Total
Northern Sung	Ta-yao[a]	74.2	18.7	0.4	2.3	0.5	0.6	2.8	0.5	0.02	100.0
Southern Sung	Ta-yao	67.8	23.9	0.2	2.1	-.-	0.3	5.3	0.3	0.03	99.9
Southern Sung	Ta-yao	70.95	21.5	-.-	2.4	-.-	0.06	4.5	0.4	0.04	99.9
Yuan	Ta-yao	70.8	20.1	0.16	1.6	0.2	0.7	5.5	0.8	0.07	99.9
Ming	Ta-yao	70.2	20.5	0.2	1.7	0.2	0.3	6.0	1.0	0.1	100.2
Ta-yao china stone (refined)[b]		73.6	20.7	-.-	1.9	0.4	0.5	2.5	0.5	0.03	100.1

[a] All five analyses of Ta-yao bodies from Chou Jen *et al.* (1973), p. 135.
[b] *Ibid.*, p. 137.

Table 56 *Lung-chhüan celadon ware bodies from Ta-yao, collected by Nils Palmgren*[a]

Kiln site	Date	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	Total
Ta-yao	Sung	72.7	20.03	0.23	2.75	0.06	0.25	3.80	0.11	0.039	100.0
Ta-yao	Sung	70.3	20.41	0.05	2.82	0.04	0.17	5.84	0.28	0.054	100.0
Ta-yao	Sung	70.8	21.17	0.17	2.53	0.04	0.25	4.88	0.11	0.045	100.0
Ta-yao	Sung	77.1	15.82	0.17	2.53	0.02	0.22	3.98	0.09	0.031	100.0

[a] Analyses from the Research Laboratory for Archaeology and the History of Art, Oxford.

Table 57 *+10th-century siliceous stonewares from Pao-ting, southern Chekiang province, compared with Shang-lin-hu wares from northern Chekiang province*[a]

Kiln	Date	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	Total
Pao-ting	+10th C	79.8	13.6	0.5	2.1	0.2	0.4	3.01	0.35	0.03	100.0
Pao-ting	+10th C	78.7	15.1	0.4	2.3	0.05	0.4	2.8	0.2	0.045	100.0
Pao-ting	+10th C	79.4	13.2	0.5	2.6	0.1	0.4	3.4	0.4	0.05	100.1
Shang-lin-hu 上林湖	+10th C	75.7	17.2	0.7	1.7	0.4	0.5	2.8	0.9	0.013	99.9
Shang-lin-hu	+10th C	77.9	14.7	0.7	2.0	0.3	0.4	3.1	0.9	0.02	100.0
Shang-lin-hu	+10th C	75.9	17.0	0.7	1.7	0.4	0.5	2.9	0.9	0.01	100.0

[a] All analyses from the Research Laboratory for Archaeology and the History of Art, Oxford.

marked differences in alkali levels (K_2O+Na_2O) between the modern stone and the early bodies as being caused by weathering:[586]

> The Ta-yao china stone taken from the upper level of the pit differs from that taken from the lower level of the same pit. The former has been deeply weathered and so the potassium and sodium content is lower, only about 3.1%, while the latter has been much less weathered and thus contains as much as 5.2%.

Nonetheless, it is possible that some Ta-yao wares included red clay in their body recipes, as this seems to have been the case with some Southern Sung dynasty Ta-yao wares, collected by Nils Palmgren in the +1930s, and analysed at Oxford in +1984–5 (Table 56).

While it might seem eccentric of Lung-chhüan potters to have adulterated their porcelain stones with red clay, rather than to have exploited the abundant natural stoneware clays typical of the district, the ceramics that resulted from the two approaches were rather different. The key to this difference lies in the low titania levels seen in the best of the Lung-chhüan bodies. These avoided the heavier grey tones typical of southern stonewares, and also encouraged a fresher colour from the celadon glazes. There is also the important technical point that the very thick lime-alkali glazes applied to Northern Sung dynasty Lung-chhüan body-material, could well have led to shattering during cooling of the highly siliceous and lower-flux stonewares typical of the district.[587] These earlier siliceous stonewares are represented by the wares made at Pao-ting 保定, some twenty kilometres downstream from Lung-chhüan, also collected by Palmgren in the +1930s and analysed at Oxford in +1984 (Table 57).

The titania levels found in the Pao-ting wares are somewhat lower than those found in contemporary Yüeh wares from northern Chekiang province, such as those from Shang-lin-hu. This would have tended to make the bodies of

[586] *Ibid.*, p. 143.

[587] Experience of one of the authors (NW) when using a similar body to Yüeh ware from Chekiang province as a working potter in the early +1980s.

+10th-century Pao-ting wares lighter-firing, and the glazes less grey, than those in the north of the province. Wares with these paler characteristics certainly tend to be more typical of southern Chekiang province.[588]

The Porcellaneous Lung-chhüan Material

The result of this interesting adaptation of porcelain technology at the Lung-chhüan kilns was a tough, attractive and versatile celadon material that was ideally suited for export. Through the simple expedient of raising the iron contents of their clays and glazes, slightly beyond those provided by local porcelain materials, Lung-chhüan potters created an entirely novel style of porcelain ware. Curiously, the possibilities of this aspect of porcelain production have largely been ignored in the West.[589] By contrast, some early Japanese porcelain kilns at Arita 有田 made convincing versions of celadon wares from Chekiang province during the early +17th century.[590]

Despite the undoubted quality of the Lung-chhüan material it did not survive competition from Ching-te-chen blue-and-white. Indeed, it is somewhat paradoxical that the Lung-chhüan celadon industry began to fail at a time when Ching-te-chen was making imperial-quality celadon wares with Hsüan-Te reign period marks as a tribute to fine Lung-chhüan wares of the +13th century.[591] Besides Lung-chhüan celadon wares, Ching-te-chen also copied dark-bodied, crackled-glazed Kuan wares, starting in the +15th century. Imitations continued to be made in the Ming and the Chhing dynasties, with some examples being top-quality contemporary reinterpretations of the celadon style, while others were out-and-out fakes. In the latter class, Père d'Entrecolles described in +1712 the copying of early '*long-tsi-yen*' (Lung-chhüan) wares. A 'yellowish clay' was used, i.e. one higher in iron, for both bodies and glazes. After firing the wares were aged in a thick meat soup, refired, and then put in a sewer for a month or more. Then they then passed for being '300 or 400 years old – or at least for Ming'.[592]

Southern Sung Dynasty Kuan Ware

With its dark, wafer-thin body and thick, crackled, bluish glaze, Hang-chou Kuan ware 杭州官窯 represented the epitome of Southern Sung dynasty ceramic taste. The original ware appears to have been a southern development of Northern

[588] Vainker (1993b), pp. 34–7.

[589] Even the celebrated 'Meissen' celadon elephants, once dated to the mid +18th century have now been reattributed to the late +19th century. See Tait (1989), pp. 50–3. W. B. Honey wrote of the celadon glazes used at Meissen: 'no other European factory ever attempted to produce this glaze, until the artist potters of the present day.' See Honey (1954), p. 57.

[590] Impey (1996), see figs. 9b and 15 (unpaginated plates) for examples.

[591] A Hsüan-Te period example with an underglaze-blue reign period mark is in the Shanghai Museum, see Anon. (1996b, The Shanghai Museum), pl. 50.

[592] Tichane (1983), pp. 104–5, translation of Père d'Entrecolles' letter of +1712.

Sung imperial Ju ware 汝窯. Ju ware had its main production cut short by the loss of north China to the Tartar invaders in +1127, and the consequent flight of the imperial court south, which after many travels eventually settled in Hang-chou and attempted to reconstruct the norms of court life. One requirement was exquisite ceramics for imperial use, and to this end kilns were established in the vicinity of Hang-chou.

According to traditional records, early in the Southern Sung period new kilns to supply the court were established at Hang-chou.[593] The records state that there were two kilns, one near the palace precincts under the direction of the Palace Maintenance Office (*Hsiu-nei Ssu* 修內司)[594] the other on the outskirts of the city by the Altar for Sacrificing to Heaven (*Chiao-than Hsia* 郊壇下).

Kuan ware quickly became famous, and references to it occur early. One of the earliest was made by Ku Wen-Chien 顧文薦 in the late Southern Sung dynasty, who wrote:[595]

> The present administration judged the white porcelain of Ting-chou unfit for use, and thus ordered Ju-chou 汝州 to produce celadon ware. Thereafter the kilns in Thang-chou 唐州 in Hopei, Teng-chou 鄧州 and Yao-chou 耀州 all followed this order. Ju ware is the finest of them all, whereas the materials from the Lung-chhüan district kiln of Chhu-chou 處州 in Chiang-nan are somewhat coarse and thick. In the Hsüan-Cheng reign period (+1111–25) a kiln was established in the capital itself to fire porcelain, called Kuan ware. After the movement of the capital across the river [i.e. Southern Sung] a certain Shao Chheng-Chang 邵成章 was put in charge of production in the Rear Garden, which came to be called Shao's Bureau, and which adopted the system that had been used in the old capital. A kiln was established in Hsiu-nei Ssu to make celadon ware, called 'inner ware' (*nei-yao* 內窯) and made by use of refined-clay moulds, creating an extremely exquisite effect. The colour is clear and transparent, and greatly treasured by the present generation. Later a new kiln was set up at Chiao-than Hsia, but its products were not in the same league as those of the older kiln. Other wares . . . do not compare with Kuan ware, and as for the old Yüeh kilns, they no longer exist.

Kuan ware has always been popular with connoisseurs, mentioned by Tshao Chao at the beginning of the Ming dynasty and included in all the collectors' lists of 'Five Great Wares'. In the Chhing dynasty it was so admired that imperial orders for copies were placed at the imperial factory at Ching-te-chen, in similar fashion to those for Chün ware. Royal commands were sent in +1729 to make a reproduction of a

[593] Ts'ai Ho-Pi (1989), pp. 123–6, argues that because no mention is made in texts before +1149 of kilns in Hang-chou, and because the capital moved three times in the early Southern Sung period, Kuan ware kilns could equally have been situated in Yüeh-chou 越州, Su-chou 蘇州 or other locations prior to +1149.

[594] For details see Hucker (1985), p. 248. The office was temporarily responsible for ceramics manufacture from the late Northern Sung dynasty, cf. Li He (1998), p. 12.

[595] *Fu Hsüan Tsa Lu*, translated in Ts'ai Ho-Pi (1989), p. 26, who discusses the variability of textual references on pp. 9–13, 27–9. Ku Wen-Chien's original text is lost, and has only been preserved in *(Nan Tshun) Chho Keng Lu* (+1366). Modern scholarship reveals that the eunuch Shao Chheng-Chang, although he did serve the Hui-Tsung emperor (*r.* +1101–25), was dismissed and exiled and never returned to court, so he could not have supervised porcelain after the move south. However, another Shao (with a different given name) was cited in other records as Supervisor. Tsai Ho-Pi (1989), p. 110, note 2. Li He (1998), p. 13, also lists textual references to Kuan ware on p. 16.

large gourd-shaped Kuan ware vase sent from Peking and the potters were asked to differentiate between the old and the new as a test. Most copies bore the name of the reigning monarch, but in +1745 an order was received to make imitation Kuan and Ko wares 哥窯 with no marks.[596] Around that time commercial factories in the city started to make Kuan-style and Ko-style porcelains for an ever-expanding market.

THE TWO KUAN KILNS AT HANG-CHOU: HSIU-NEI SSU AND CHIAO-THAN HSIA

Ceramics from the later of the two Kuan kiln sites, Chiao-than Hsia, have been known about since the +1930s.[597] Trial digging was carried out there in +1956, a thorough survey and excavation not being accomplished till +1984–6. The site now houses a large museum devoted to the history and production of Kuan ware, preserved sections of the workshop areas, and the largest of three dragon kilns that were unearthed. Of the three kilns, two were of traditional size while the third was very large, measuring 80 metres in length and 3 metres across. Its size, almost three times as long as those used in the +9th to +10th centuries for Yüeh ware, implies considerable experimentation, extensive organisation of labour and raw materials, and high fuel costs.[598] Excavators also unearthed a large shop, three house foundations, one clay-refining pit, two vats for glaze, a storage pit for raw materials, a biscuit-firing kiln, more than 30,000 sherds[599] and thousands of tools and kiln furniture.[600] It appeared that early Kuan copied Ju ware firing methods, being fired on between three and nine small round spurs. Large vases and other big thick-bodied wares were fired on pads, the base being left unglazed. Some kiln furniture (for example, three-pronged supports, cylinder supports and ring supports) were very similar to those found at the Ju kiln at Chhing-liang-ssu 清涼寺 in Honan province. Because of the thickness of the glaze layers on some later Kuan wares small spurs could stick, so instead glaze was wiped from the footring and pieces were fired on pads.

Until recently, the earlier of the two sites, Hsiu-nei Ssu, had not positively been identified, though several sites had been claimed for it. Before the site was actually discovered, some scholars suggested that its name may simply have linked the kiln with the bureaucratic department Hsiu-nei Ssu, and that the kiln did not exist. Other scholars identified the kiln as being one and the same as Chiao-than Hsia.[601]

[596] Fu Chen-Lun & Chen Li (1982), pp. 21–2, 43–4, 55–6, 62.

[597] Chu Hung-Ta 朱鴻達 published his *Hsiu-nei Ssu Kuan Yao Thu Chieh* in +1937, its findings summarising research to date, see Yang Ching-Jung (1987b), pp. 42, 96.

[598] Vandiver (1992), p. 134.

[599] The sherds with crackled celadon glazes of various shades were very similar to fine, crackled ceramics made at Lung-chhüan, so-called 'Lung-chhüan Kuan ware 龍泉官窯', see pp. 582–4.

[600] Cf. Anon. (1996a), pp. 15–18, kiln drawings and description.

[601] Current Chinese theories concerning the Hsiu-nei Ssu kiln are outlined by Ts'ai Ho-Pi (1989), pp. 124–6, and Li He (1998), pp. 12–13. Li Hui-Ping (1998) has published a subsequent article.

In +1996, what is generally acknowledged to be the Hsiu-nei Ssu kiln was finally excavated. The site is on hilly slopes to the south of the modern city of Hang-chou, and just outside the walls of the Southern Sung dynasty imperial city.[602] The kiln, known to archaeologists as Lao-hu-tung 老虎洞 (Tiger Cave) was dug after surface finds had alerted the authorities to its location. After five seasons' excavations, archaeologists have worked through a Yuan dynasty stratum, which marked the latest period of activity for the kiln. Material from this layer was thick-bodied and thin-glazed, and its general quality indicated that it was non-imperial ware, in spite of one sherd base with a crudely painted inscription reading *kuan yao* 官窯 (official ware). Beneath the Yuan stratum was Southern Sung material, which was of much finer quality. In addition, the Southern Sung waster sherds had been carefully gathered and buried in two pits, suggesting that disposal of imperial wares was strictly controlled. Body-materials ranged from grey to black, and many had the appearance of 'purple mouth and iron foot' (*tzu-khou thieh-tzu* 紫口鐵足, see p. 581). Glaze quality varied, but the best examples had thin bodies over which thick dove-blue glaze was applied in several layers, often showing fine crackle. In addition to sherd material, the excavators also found one dragon kiln some fifteen metres in length, three biscuit kilns and a workshop area in which glaze vats were clearly preserved.[603]

The authors were fortunate to visit Lao-hu-tung while it was being excavated in November +1999, and again when excavations were complete in November +2001. Seminars on the kiln's discovery were accompanied by displays of many sherds from the site. Archaeologists working on the Lao-hu-tung excavations explained that a traditional dragon kiln, used for firing Yüeh type wares, had been commandeered at Lao-hu-tung for Kuan ware production, and that a series of small *mantou* kilns (the typical northern type) had also been found at the site. These smaller kilns had been used for biscuit-firing the Kuan wares (very much a northern practice).

THE LAO-HU-TUNG SHERDS

The sherds analysed in Table 58 were surface finds from the Lao-hu-tung kiln, material that scientists as well as archaeologists believed to be from the Hsiu-nei Ssu imperial kiln:[604]

> The kiln site of Southern Sung stratum Lao-hu-tong should be the 'Nei-yao' (Imperial kiln) recorded in Yeh Chih's '*Than Chai Pi Heng*' which is [the] Hsiu-nei Ssu kiln . . .

[602] The Hsiu-nei Ssu kiln (Lao-hu-tung) is also only 2.5 kilometres north of the Chiao-than Hsia kiln, in a direct line across an intervening hill. Thus it seems that Hsiu-nei Ssu was established first, very close to the Southern Sung city. Chiao-than Hsia was established second, at a greater distance from the city and with an intervening range of hills to mask noise and smoke.

[603] See Tu Cheng-Hsien (1999).

[604] Li Chia-Chih *et al.* (1999). (Expanded English text on the Lao-hu-tung finds, supplied with the Chinese 'Proceedings'.)

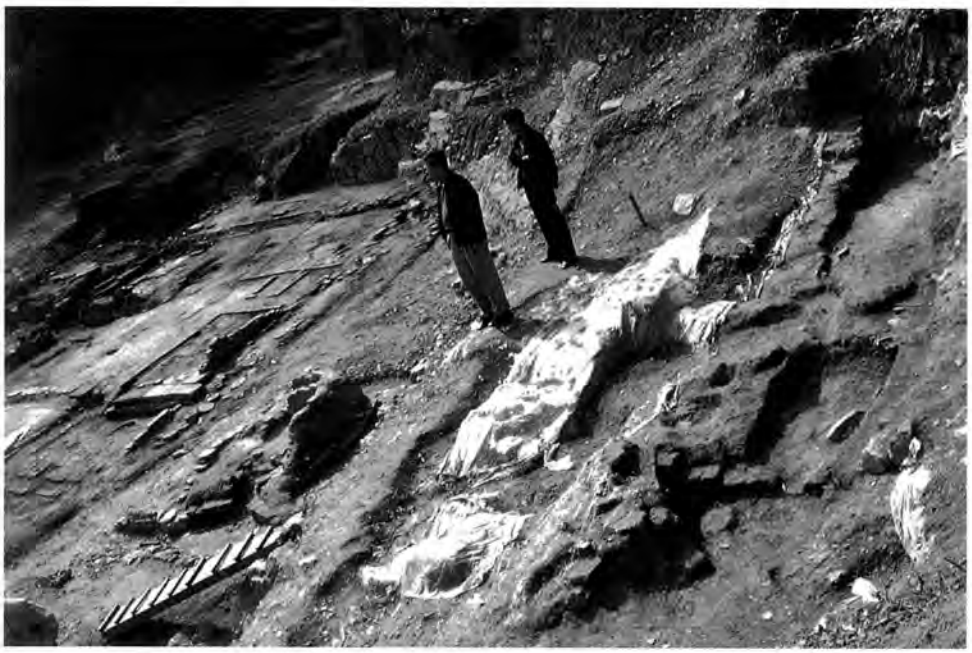


Fig. 52 Narrow dragon kiln at Lao-hu-tung, 15 metres long and 2 metres wide (at right of picture), +2001



Fig. 53 *Man-thou* kiln at Lao-hu-tung for biscuit-firing wares, +2001

Table 58 *Compositions of Kuan ware bodies from Lao-hu-tung*[a]

Bodies from Lao-hu-tung, Hang-chou	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Total
Kuan ware, Lao-hu-tung	68.2	25.0	1.05	2.4	0.07	0.1	2.3	0.4	0.01	0.06	99.6
Kuan ware, Lao-hu-tung	68.5	25.0	1.1	2.25	0.08	0.1	2.3	0.3	0.002	0.02	99.7
Kuan ware, Lao-hu-tung	67.0	25.0	1.15	2.0	0.2	0.2	3.4	0.4	0.012	0.3	99.7
Kuan ware, Lao-hu-tung	68.2	23.0	1.0	2.6	0.1	0.3	3.5	0.4	0.01	0.25	99.4
Kuan ware, Lao-hu-tung HX14	67.3	21.9	1.1	3.9	0.3	0.4	3.6	0.7	0.02	0.1	99.3
Kuan ware, Lao-hu-tung HX15	68.5	23.1	1.0	3.3	0.1	0.3	2.4	0.5	0.02	0.1	99.3

[a] Li Chia-Chih *et al.* (1999), p. 177, table 1.

Table 59 *Kuan ware bodies from northern and southern Chekiang province compared*[a]

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Total
Bodies: Hang-chou Kuan											
Kuan ware, Chiao-than Hsia	61.3	28.0	0.7	4.1	0.2	0.6	4.2	0.2	-.-	0.08	99.4
Kuan ware, Chiao-than Hsia	66.5	23.1	1.2	3.0	0.3	0.2	3.7	0.3	-.-	-.-	98.3
Kuan ware, Chiao-than Hsia	69.8	20.6	0.7	3.1	0.3	0.7	3.7	0.4	-.-	0.08	99.4
Kuan ware, Chiao-than Hsia	70.1	21.2	1.0	3.2	0.1	0.4	2.6	0.2	-.-	0.09	98.9
Bodies: Lung-chhüan Kuan											
Kuan-type[b]	61.4	28.0	0.7	4.5	0.9	0.7	3.7	0.4	0.2	-.-	100.5
Kuan-type	64.2	25.2	0.8	4.5	0.2	0.6	4.0	0.1	-.-	0.13	99.7
Kuan-type	62.7	28.7	-.-	3.7	0.5	0.5	4.1	0.1	-.-	-.-	100.3
Kuan-type	64.9	24.2	-.-	3.6	0.5	0.2	4.7	0.2	0.04	-.-	98.3
Kuan-type	63.3	26.1	-.-	4.6	0.5	0.3	3.7	0.2	-.-	-.-	98.7
Red clays: Lung-chhüan											
Kao-chi-thou red clay (prepared)	62.2	21.5	0.5	4.3	0.7	0.9	4.7	1.1	0.1	-.-	96.0
Mu-tai-khou red clay (prepared)	63.1	26.6	0.85	5.2	0.2	0.35	3.2	0.4	-.-	-.-	99.9

[a] Chen Xianqiu *et al.* (1986), p. 164, tables 3 and 4.
[b] Chou Jen *et al.* (1973), p. 135.

The body compositions of some Chiao-than Hsia sherds are given in Table 59, and, like the Lung-chhüan Kuan ware sherds that imitate them, have relatively high iron oxide contents at between 3–4.5%. The first four Lao-hu-tung sherds in Table 58, by contrast, average 2.3% Fe_2O_3, and are near to Ju ware clays in their iron contents (see Table 28). However, the last two analyses show higher iron contents that average 3.5% Fe_2O_3, making them much darker firing. Li Chia-Chih *et al.* note that these two examples have:[605]

> grey dark bodies, crackled grey green glazes and purple rim can be seen. These sherds are very similar to the handed down Ko ware collected in Palace Museum (Peking).

Where the Hang-chou potters derived the concept of using a dark stoneware body with a thick, crackled celadon glaze is a complex problem. Northern Ju ware clays were rather pale materials (with an average of 2% Fe_2O_3), and Ju wares were initially copied at Hang-chou with relatively light-firing bodies, similar to those used for early Southern Sung 'Hang-chou Yüeh' wares.[606]

Whether these latter sherds represent early experiments with dark-firing bodies for the first southern Kuan ware, or the later, revived, stage of production at the Nei kiln is also hard to say, as they are surface finds rather than from properly stratified excavations. Their glazes, though, conform to the lower-lime levels that are typical of the paler sherds, so may well be contemporary with them. It is possible therefore that the effects produced by these darker clays gradually came to be preferred by the principals of the Hsiu-nei Ssu kilns, thereby moving the Kuan ware style away from Ju ware and setting the style for darker-bodied ceramics. It was this darker-bodied ware that became typical of Chiao-than Hsia and Lung-chhüan Kuan ware production.

HANG-CHOU AND LUNG-CHHÜAN KUAN WARES

Imperial Kuan wares made at Hang-chou in northern Chekiang province were copied by several of the Lung-chhüan kilns in southern Chekiang. Chou Jen and his colleagues included a single example of black-bodied Lung-chhüan ware in their study. The authors noted that:[607]

> Obviously a large amount of red clay was added to the body clay. The chemical composition of the glaze is rather similar to that of general Lung-chhüan celadon glaze . . . and is crackled. Looked at from every aspect, it is a direct descendent of Southern Sung Kuan ware and utterly different from celadons of the Lung-chhüan tradition. It resembles Southern Sung Kuan ware in shape of the vessel, colour of the glaze, crackle and the form in which the foot is cut. The two are very difficult to distinguish by appearance.

[605] Li Chia-Chih *et al.* (1999), p. 1.

[606] Yüeh-type sherds have been excavated at Lao-hu-tung in the same context as early Kuan wares. Scott (1993b), p. 18, illustrates a light-bodied incense burner, now in the Percival David Foundation collection, and suggests that this may be a product of the Hsiu-nei Ssu kiln.

[607] Chou Jen *et al.* (1973), p. 153.

Chou Jen established that a number of Lung-chhüan kiln sites (for example, kilns 12, 31, 36 and 50 at Ta-yao itself, and the Wa-yao-yang kiln 瓦窯垟窯 at Hsi-khou 溪口) produced copies of Southern Sung imperial Kuan ware from Hang-chou.[608] Chou *et al.* describe the black-bodied Lung-chhüan sherds as follows:

> Many black-bodied fragments unearthed at Ta-yao and Hsi-K'ou were also examined. There were great differences in appearance due to differences in the firing temperatures of the fragments. The bodies fired in higher temperatures appear a deep grey black and in cross-section bear a close resemblance to the seams in a coal mine. Bodies fired in progressively lower temperatures appear proportionately lighter.

The good correlations between Lung-chhüan Kuan-type bodies and typical Lung-chhüan-area red clays suggests that 'Lung-chhüan Kuan ware' could well have been made from a single prepared material (a local red clay), and was therefore not necessarily a 'contrived' body, based on heavily adulterated porcelain stone.

Perhaps the most impressive aspect of the Lung-chhüan copying of imperial Kuan ware appears in the very exact match achieved between kiln sites situated some 300 kilometres apart. The imitation of famous wares with local materials is a familiar theme in Chinese ceramics, but the results are usually local interpretations, rather than exact copies. The glazes, clays, forms and firing arrangements of imperial Kuan ware from Hang-chou were all reproduced exactly at Lung-chhüan. That may suggest that potters expert in Kuan ware production were sent from Hang-chou to the Lung-chhüan district to assist the process.

As Table 59 demonstrates, the bodies used for both Kuan ware from Hang-chou and Kuan-type wares from Lung-chhüan were high in iron and potassium oxides. Black iron oxide, iron (II) oxide (FeO), develops during reduction-firings, and is a powerful body-flux. Its above-average presence in these clays resulted in rather over-fluxed stonewares with coal-like fractures that were only suitable for firing in the lower stoneware range. Fortunately the lime glazes developed for Kuan wares from the lime glazes used on Ju wares matured at similar temperatures of *c.* 1,220°C. Thus the Kuan ware clays from both Hang-chou and Lung-chhüan were not taken to quite their firing limits. Even so, a strong interaction between glaze and body is evident in many Kuan wares, most notably in the 'purple mouth' effect, where the thinner glaze at the rim of Kuan ware vessels allowed the ferruginous clay beneath to reoxidise somewhat to a purplish-brown tone.

THE CONTINUING MYSTERY OF KO WARE 哥窯

Identification of another crackle-glazed ceramic closely associated with Kuan ware is much more contentious. A traditional view is that this Ko ware was simply a variant of Kuan ware, composed and fired under differing conditions. Certainly

[608] *Ibid.*, p. 154.

crackle-glazed ceramics of widely varying colour and texture could in theory simply be affected by atmosphere during firing, temperature and cooling processes.[609]

Traditional texts have tended to foster a connection between Ko ware and Kuan ware. For example, Khung Chhi 孔齊 writing in +1363 recorded:[610]

> In the winter of the year *i-wei* [+1355] in Hang-chou, a *Ko-ko-tung* 哥哥洞 [i.e. Ko ware] incense burner was bought. Although its fine material is new, its colour is as clear and transparent as the old ware, such that one might not be able to differentiate between them . . . The modern Ko-ko ware far exceeds ancient Kuan ware, and one should take note of this difference.

Other authorities point to specific differences in body composition, potting, firing temperature and numbers of glaze layers. Ko ware had multiple glaze layers and complex crackling and crazing. Its pattern of fine gold lines and thicker dark lines was called 'gold thread and iron wire' (*chin-ssu thieh-hsien* 金絲鐵線). The T-shaped, coarser, darker 'iron wire' crackle developed first, and the lighter 'gold thread' crazing inside it. The easiest way to produce these effects is by rapid cooling in the low temperature range, followed by deliberate staining of the darker crackle. Crazing can continue to develop, even some considerable time after firing (see p. 585).[611]

Dissenting opinions favour either Hang-chou, Lung-chhüan or north China as a place of production for Ko ware, at dates ranging from the late Southern Sung to late Yuan dynasties.[612] For example, the archaeologists working at Hang-chou proposed that the Lao-hu-tung Kuan ware kilns were restarted in the Yuan dynasty to make Ko ware, as a private, commercial venture rather than as a state-controlled imperial ware. One oddity of the finds there was the Yuan example of crackled ware inscribed 'Kuan ware' under its foot. This is believed by the archaeologists to be an attempt to cash in on the celebrity of Kuan ware at a time when the kilns were in decline.

Whatever final view prevails, Ko ware remains one of the most treasured ceramics ever made. Tshao Chao (+1388) ranked it at the top of the list of desirable wares,[613] and most connoisseurs have followed that view.[614]

[609] Scott (1993a), p. 23, cf. pls. 14 and 15.

[610] *Chih Cheng Chih Chi*, ch. 4, p. 35a. Translated by Ts'ai Ho-Pi (1989), p. 29, who notes the connection on pp. 11, 29.

[611] Chang Fu-Khang 張福康, quoted in Vainker (1993a), p. 11. Delayed crazing is caused by body expansion with moisture, and it cannot be microstructurally differentiated from crackle produced by rapid cooling in the kiln. Both produce cracks in the glaze when it shrinks more than the body, to the point that its breaking strength is exceeded.

[612] *Ibid.*, pp. 7–11.

[613] *Ko Ku Yao Lun*, ch. 3, p. 38b. David (1971), pp. 140, 307.

[614] Lu Ming-Hua 陸明華 has compiled a list of texts on Ko ware, from the Yuan dynasty onwards, cf. Vainker (1993a), pp. 10–11.

Dark-Bodied Stonewares in South China

Paradoxically, stoneware clays with nearly double the amounts of iron oxide found in Kuan wares were fired to some of the highest stoneware temperatures used in south China (*c.* 1,300°C ± 20°). This was possible because the kilns were fired in oxidation, causing the iron oxide in the clays to take mainly the iron (III) rather than the iron (II) state, where it acted only as a mild flux. The most important use for these highly-iron stoneware clays was for the making of *tenmoku* 天目 wares, which had their main producing kilns in northern Fukien province, in a mountainous district some 200 kilometres to the south of Lung-chhüan.

The first use for these clays in Fukien appears to have been for making low-fired unglazed earthenware in the Neolithic period,[615] but their rediscovery for the making of high-fired glazed wares seems to have occurred in the late Thang dynasty, when they were used as the bodies for some small and dark-bodied black-glazed tea-bowls.[616]

It seems possible that this new body-glaze combination appeared through the well-tried southern practice of mixing wood ash with the local body-clay to make a stoneware glaze. When the principle was applied to the northern Fukien province ferruginous clays the result was a brown-black glaze on a dark clay body, the best type becoming known as 'Chien ware 建窯'.[617]

Chien Ware

Chien wares were made in Chien-yang county 建陽縣 in northern Fukien from the late Thang to the end of the Yuan dynasty. The kilns were investigated by the American scholar and Chinese customs official James Marshall Plumer in +1935,[618] and subsequently in more detail by Chinese archaeologists in +1960, +1977 and in +1988–92, the latter major excavations leading to the discovery of ten kilns.[619] Of these one kiln was late Thang dynasty, one was Five Dynasties period, seven were Sung and one Yuan. Sherds found there were not solely black-bodied and black-glazed ware, but also celadon and *chhing-pai*. This range of wares was common to several kilns in the northern part of Fukien province.

All the kilns excavated were climbing 'dragon' kilns, with none of the stepped, chambered type. The Thang and Five Dynasties kilns were constructed using mud walls, while bricks were employed in the Sung and Yuan dynasty kilns. Two Northern

[615] Luo Hongjie (1996), database.
[616] Chen Xianqiu *et al.* (1986c), p. 236, table 2.
[617] Wood (1999), pp. 146–7.
[618] Plumer (1935); Marshall Wu (1998), pp. 22–4.
[619] Yeh Wen-Chheng & Lin Chung-Kan (1993), p. 184, note 1.



Fig. 54 'Arabella, queen sow of the village of Ta-lu 大爐 near the kiln sites, dines in luxury from a genuine Temmoku sagger', +1935



Fig. 55 'Chien-yao tea-bowls in household use today; excavated from the neighbouring Sung waste piles; a simple farmer's family at home', +1935

Table 60 *Chien ware stoneware bodies: Sung and Yuan dynasties*[a]

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	loss	Total
Sung Chien body	64.8	22.25	1.6	8.8	0.04	0.5	2.2	0.07	0.08	-.-.	0.4	100.7
Sung Chien body	63.3	23.1	1.1	9.65	0.2	0.4	2.5	0.06	0.09	-.-.	0.6	101.0
Sung Chien body	63.1	23.2	1.6	8.2	0.1	0.5	2.7	0.06	0.12	-.-.	0.6	100.2
Fukien Neolithic clay[b]	57.5	29.0	0.8	8.5	0.4	0.7	2.6	0.4	0.04	0.13		100.1

[a] From Chen Xianqiu *et al.* (1986c), p. 236, table 2.
[b] Luo Hongjie (1996), database.

Sung dynasty kilns were unusually long, being over 100 metres in length when the average was 50–80 metres. Of these, one constructed on a 60° slope was the largest in China, at 135.6 metres in length and 0.95–2.3 metres in width. It was estimated that this kiln could produce 100,000 vessels in a single firing.[620]

In the +10th and +11th centuries Chien ware tea-bowls became larger and their glazes thicker, and they developed a remarkable oily brown-black streakiness, similar to animal-fur. This change in appearance seems to have been due to the use of thicker glazes, less wood ash in the glaze recipes, and the use of more elevated kiln temperatures than those general in the Thang dynasty (Table 60).

Chien ware kilns made exclusively teawares, and these were fired singly in saggers using clay separators. Marshall Wu has shown how these separators were made from wet clay into which the tea-bowls were pushed, securing them during firing. When the separators did not keep the bowls exactly upright, the glaze pooled unevenly, an effect observed on many pieces.[621]

The most valued Chien ware glaze effects, and those that were described admiringly in literature, were so-called 'oil spot' (*yu-ti* 油滴), 'hare's fur' (*thu-hao* 兔毫) and 'partridge feather' (*che-ku* 鷓鴣) glazes. Most were intentionally cultivated effects of phase-separation, while the distinctive white-spotted partridge-feather glaze was often aided by the application of white spots of glaze.[622] Partridge feather glaze was discussed by Thao Ku 陶谷, who wrote *c.* +965–70:[623]

> Tea-bowls with partridge feather markings are made in Fukien and this type is treasured by tea masters. For this reason I showed [them] a painting of partridges from Szechuan in my study.

The connection of Chien ware with tea-drinking leads us on to consider the whole phenomenon of the cult, and of the ceramics associated with it.

[620] Zeng Fan (1997b), pp. 30–1.
[621] Marshall Wu (1998), pp. 23–4.
[622] Chen Xianqiu *et al.* (1992a). A range of Chien wares, with differing bodies and glazes, is illustrated in Anon. (1994c); the famous excavated sherd with partridge feather spots and mark *kung yü* 供御 is on p. 61. Chang Fu-Khang (2000) discusses the technology of oil spot and hare's fur glazes on pp. 86–9.
[623] *Chhing I Lu*, ch. 2, pp. 14–15.

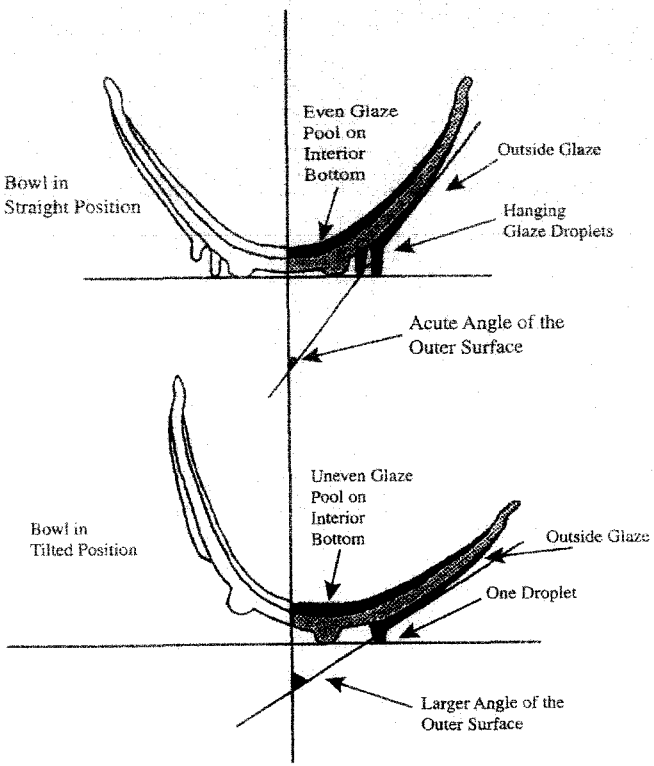


Fig. 56 Glaze flow on Chien ware bowls placed at different angles during firing

TEA-DRINKING AND TEAWARES

Many countries in the world have enjoyed stimulant benefits of tea-drinking, but it is generally acknowledged that the habit was practised earliest in China. Its legendary beginning was with Shen Nung 神農, the Deity of Agriculture who taught early peoples how to cultivate different crops.[624] Having sampled 100 wild herbs of which 70 were toxic, Shen Nung sought relief by drinking tea.[625] As is common, this mythical reference encoded a message, namely that the earliest use of the tea plant was probably medicinal.

[624] Bray (1984) discusses Shen Nung, pp. 36(a), 99, 144, 159, 481. H. T. Huang (2000) mentions the legend connected with the deity, who he tides 'The Heavenly Husbandman', on. pp. 503–5.
[625] Sung Po-Yin (1984), pp. 14, 20.

The wild tea plant is related to the flowering bush camellia, and comes from a plant called *Camellia sinensis* which without human intervention will grow to the size of a tree.[626] It grew wild among the mountains and rivers of Szechuan and Hupei.[627] As early as the Western Han dynasty passing references alluded to the fact that tea was a commodity for sale on the open market.[628] By the +3rd century references to tea, and knowledge about its properties, were more commonplace as some sample quotations show:

The plant is small . . . it grows leaves in the winter time which may be boiled to make a beverage for drinking. Today those that are gathered early are called *thu* 荼 (i.e. modern *chha* 茶), those that are gathered late are called *ming* 茗, and another name for them is *chhüan* 荈.[629]

In the districts between Hupei and Szechuan, tea leaves are plucked and dried into cakes.[630]

The drinking of real tea will cause people to suffer lack of sleep.[631]

Someone secretly gave [Wei Chao 韋昭] some tea to take the place of wine.[632]

HSING 邢窯 AND YÜEH 越窯 TEAWARES

The practice of tea-consumption spread in the period *c.* +300–700, and became widespread in the Chiang-nan region. But it was in the Thang dynasty that tea-drinking rose to cult status and engendered a miscellany of manuals on tea, and books of odes and rhapsodies on the same subject (see bibliography A and note 628). Ku Khuang's 顧況 *Chha Fu* (Rhapsody on Tea) of *c.* +757 made the standard comparison between Yüeh ware and jade. Lu Yu's 陸羽 *Chha Ching* (The Classic of Tea) of *c.* +761 favoured Yüeh ware above Hsing ware, which it likened to ice. It also explained how tea types were savoured in contrasting ceramic bowls and cups, white Hsing porcelain acting as a foil to red tea and greenish-blue Yüeh ware complementing green tea.[633] In spite of Lu Yu's views, historical sources suggest that white Hsing porcelain from Hopei province was valued and widely used.[634]

However, it was Yüeh ware that poets extolled more often, by means of oblique references in their verse. The corpus of Thang poetry assembled in *Chhin Ting*

[626] Daniels (1996), pp. 28–30.

[627] Sung Po-Yin (1984), pp. 8, 14.

[628] In −59 a court official, Wang Pao 王褒, entered into a mock contract with a boy servant, contained within which is the phrase 'buying tea from Wu-yang 武陽 (i.e. Szechuan)'. The reference is in *Han Wei Ming Wen Sheng*, bk. 11, ch. 12 ('*Thung Yüeh*'), quoted in Sung Po-Yin (1984), pp. 14, 17, 20. The quote is discussed in H. T. Huang (2000), p. 508, note 19. That volume includes an exhaustive discussion of early texts on tea on pp. 507–19.

[629] Kuo Phu 郭璞 (+276–324) in commentary to *Erh Ya*, trans. Bodde (1942), pp. 74–6. The quote is employed by H. T. Huang (2000), p. 508.

[630] *Kuang Ya*, quoted in *Thai Phing Yü Lan*, ch. 867 ('*Yin shih*'), p. 3761.

[631] A reference in *Po Wu Chih* dating between *c.*+265 and +289, ch. 4, p. 2b. Bodde (1942), pp. 74–6.

[632] *San Kuo Chih*, ch. 20 ('*Wu Chih*'), p. 1462. The historian Wei Chao 韋昭 was invited to drunken feasts given by the dissolute ruler of the Wu Kingdom, Sun Hao 吳國孫皓. Wei Chao was in poor health and could not keep up with the massive consumption of alcohol, so some kind person came to his aid by substituting tea. This reference can be dated between +264 and +273. Bodde (1942), pp. 74–6; H. T. Huang (2000), p. 509, note 22.

[633] *Chha Ching* ('Wan'), p. 9b.

[634] *Kuo Shih Phu* ('*Shu Chung Chi*'), p. 5b.

Chhüan Thang Shih (Corpus of Thang poetry, +1707) contained 35 references to porcelain, with eight mentions of Yüeh ware alone dating before +881.[635] For example, Meng Chiao 孟郊 (+751–814) wrote:[636]

The jade flowers covering tender tea leaves have sunk down to the dregs, the Yüeh ware lotus-bowl is empty.

玉花盡, 越甌荷葉空.

Phi Jih-Hsiu 皮日休 (?+834–?+883) wrote more directly:[637]

Hsing potters and Yüeh potters both know how to make fine ceramics, round as the soul of the sinking moon, light as the spirit of the rising clouds.

邢人與越人, 皆能造瓷器, 圓似月魄墮, 輕如云魂起.

The earliest reference to the very highest quality *mi-se* 密色 ('secret colour') Yüeh ware[638] occurred in an ode by Lu Kuei-Meng 陸龜蒙 (*d.* +881) entitled *Mi-se Yüeh Chhi*, 'Secret Coloured Yüeh Ware', in which the poet compared its subtle colouration to a myriad kingfisher-green mountain peaks (九秋風露越窯開, 奪得千峰翠色來).[639]

Yüeh ware bowls also did duty for wine-drinking at court in the +8th century:[640]

The Palace Storehouses (*Nei-khu* 內庫) held green porcelain wine cups, with markings like tangled silk threads, that were as thin as paper. They were for pouring warmed wine, and were also called warming cups.

Porcelain wine cups were even used as musical instruments, because of the clear resonant sound they emitted when tapped. The Wu-Tsung emperor (*r.* +841–846) enjoyed beautiful notes struck from a dozen Yüeh and Hsing ware bowls, filled with different volumes of water and tapped with chopsticks to provide notes.[641]

Bowls were the items most often mentioned by Thang writers but they were not the only utensils associated with the tea ritual. Small ewers were also employed interchangeably for tea and wine, and stands or saucers were added to make hot vessels easier to lift and hold. The +12th-century Sung dynasty scholar Chheng Ta-Chhang 程大昌 explained their introduction to the Thang court from the south-west by the daughter of Tshui Ning 崔寧女 (+779) who used melted wax to fit a

[635] Sung Po-Yin (1995), pp. 2–5.
[636] '*Phing Chou Khuang Hsien Pei Yü Chhao Hsien Chhi Chha* 憑周況先輩於朝賢乞茶', in *Chhin Ting Chhüan Thang Shih*, *Tshe* 6, ch. 380, p. 4266.
[637] '*Chha Ou Shih* 茶甌詩', in *Chhin Ting Chhüan Thang Shih*, *Tshe* 7, ch. 611, p. 7055.
[638] The meaning of the term '*mi-se*' is debated by scholars, some contending that it was confused with *pi* 碧 meaning blue/green, others that it derived from a green herb *mi* (蔤), and yet others that its translation as 'secret', 'forbidden' or 'rare' referred to its use as an official tribute ware not permitted to commoners. If the latter explanation is accepted, it must remain a question why so much high-quality Yüeh ware was exported, as has been proved by excavation in several countries outside China, see pp. 728–32 of this volume.
[639] '*Mi-se Yüeh Chhi* 密色越器', in *Chhin Ting Chhüan Thang Shu*, *Tshe* 10, ch. 629, p. 7219.
[640] *Khai Yüan Thien Pao I Shih* ('*Tzu Tshai Pei*'), p. 4b.
[641] *Yüeh Fu Tsa Lu*, p. 33.

tea-bowl inside a plate,[642] though it seems from the material evidence that saucers were in use prior to that time. Cup and bowl stands, either made separately or in a piece with the cup or bowl, were common among Thang dynasty Yüeh ware and Sung dynasty Kuan, Ting, celadon, black-glazed and *chhing-pai* ware.

SUNG DYNASTY TEAWARES

In the Sung dynasty, among the most admired vessels were black-glazed tea-bowls with phase-separated glazes super-saturated with iron, that produced streaked and spotted effects the most prized of which were gold, silver and iridescent glaze effects. These bowls were mainly Chien ware from Fukien, but also Chi-chou ware 吉州窯 from Chiangsu and blackwares from north China. The experience of drinking tea from bowls displaying such exotic patterns gave rise to a quantity of poetry and prose.[643] Typical was the poet Su Tung-Pho 蘇東坡:[644]

The Taoist master comes down the winding path out of the Nan-phing mountains, in order to sample three handfuls of dark tea. With carefree mind he mixes 'conjugal happiness' wine in his spring jar at noon, his saucer having 'hare's fur' markings.

道人繞出南屏山, 來試點茶三昧手, 勿驚午盞兔毛斑, 打出春甕鵝兒酒.

Yuan tea-drinking customs do not seem to have changed to a significant degree, but in the Ming dynasty considerable changes took place in tea preparation, and in preferences for tea vessels.[645] Thick Chien ware with its mottled black glaze was out of favour, and instead fine, white porcelain was sought. Sung dynasty Ting ware 定窯 was the favourite type, and many copies were made. Early in the dynasty (+1388), Tshao Chao noted the popularity of ancient Ting bowls, their use changed from its original purpose to that of tea-drinking.[646] White porcelain of the Hsüan-Te reign period came next in favour, followed by Chheng-Hua and Chia-Ching vessels and delicate blue-and-white. The Ming dynasty connoisseurial position was summed up by such writers as Thu Lung 屠隆, Kao Lien 高濂 and Hsü Tzhu-Shu 許次紓.[647]

I-HSING TEAWARES

From the middle Ming period teapots to contain leaf-tea brew came into use, and I-hsing 宜興 red stoneware supplied some of the most coveted products. In fact, I-hsing teapots came to enjoy as much affection with the Chinese people in the

[642] *Yen Fan Lu*, ch. 15 ('*Tho Tzu*') pp. 7a–b.
[643] Feng Hsien-Ming (1987), p. 8, pls. 2–6.
[644] *Sung Nan Phing Chhien Shih* 送南屏謙師, in *Thien Men Wen Tzu Chhan* 天門文字禪, ch. 8, p. 11a, quoted in Feng Hsien-Ming (1987), p. 8.
[645] For the history and evolution of tea preparation see Anon. (1984b); Chao Chin-Chheng (1990).
[646] *Kō Ku Yao Lun*, ch. 3, p. 41a; David (1971), pp. 144, 304.
[647] Feng Hsien-Ming (1987), p. 9.





Fig. 57 Kung Chhun teapot with maker's mark and date of +1513

Ming and Chhing dynasties as Chien wares had found in the Sung and Yuan periods. I-hsing teapots also became a vehicle for some of the most inventive ceramic design in China, and this creative spirit in the making of I-hsing teawares continues undiminished today.

I-hsing teapots were often signed by their makers, and this gave an added cachet to wares from the most famous potters. Wen Chen-Heng 文震亨 opined in +1645 that:[648]

> Kung-chhun teapots are the most valuable, because their shapes are not over-elegant and their capacity is not too small, whereas those made by Shih Ta-Pin are too small.

Here Wen was name-dropping two of the most famous early I-hsing potters, Kung Chhun 供春 (active early to mid +16th century) and Shih Ta-Pin 時大彬 (active late +16th century).

The I-hsing region was a famous tea-producing area at least as early as the Thang dynasty. Lying between the major cities of Nanking, Su-chou and Shanghai, it became in the Ming and Chhing dynasties a natural centre for scholars, merchants and connoisseurs to congregate. 'Purple clay' (*tzu-sha* 紫砂) teawares had been made there since the mid Northern Sung dynasty, though manufacture flourished from the +16th century. An interesting feature of I-hsing ware is that contemporary manufacture has revived and refined processes that have been continually employed since the Ming dynasty.

[648] *Chang Wu Chih* ('*Chha-hu Chha-chan*'), p. 2b.

I-hsing wares were fired over quite a broad temperature range of 1,190–1,270°C. The properties of raw materials, forming and firing ensured that I-hsing wares had qualities especially suited to tea-drinking. High porosity of up to 10% ensured that the tea maintained its colour, aroma and taste.[649] A combination of closed pores and open intermittent chain-like pores gave the material excellent insulating properties. Perhaps partly as a result of this ability to hold heat, the brewing behaviour of *tzu-sha* wares were exceptional. Good levels of tea polyphenol, coffeinum and vitamin C are maintained through the use of I-hsing teapots, and tea-colour, fragrance and taste surpass that achieved with porcelain or glass.[650] In fact, in these particulars it exceeded impervious porcelain vessels, though porcelain teawares from Ching-te-chen and other centres have always been extremely popular with tea-drinkers.

Clays compositionally similar to those used for Chien wares were used in the I-hsing area of Chiangsu province in the Northern Sung dynasty to make unglazed stonewares, including teapots, but a tendency to reduction-firing often caused fine bloating of the clays' surfaces and the colour of the ware was a purplish black.[651] By the early Ming dynasty, however, the I-hsing red clays were being fired in strict oxidation. They had been found a specialised use in the making of small unglazed hand-built and moulded vessels, associated with the drinking of tea. Clay for the distinctive reddish wares (coloured by a high iron content FeO_3 of up to 9.11%) was dug in nearby Huang-lung mountain 黃龍山.[652] It occurred deep underground, sandwiched between layers of other quartz-rich rocks, and contained hydromica, quartz, kaolin, hematite and small amounts of other materials.[653] Although naturally fine-grained it was carefully selected and levigated before use.[654] The clay was regarded as such a valuable natural resource that local entrepreneurs fought over limited supplies of the best raw materials.[655] Many of them were not potters, but individuals who sought to make money out of I-hsing's fine clays.

The high levels of iron (II) oxide (FeO) found in the early wares indicate fairly strong reduction in the kilns, while low FeO levels in later I-hsing red stonewares are signs of effective oxidation, which helped to maximise the red colours of the ware (Table 61). Nowadays the clay is found in layers 4–5 metres thick between beds of quartzite at clay mines near I-hsing. The material, which appears to be sedimentary, is a clay-quartz-hydromica-hematite mixture and is found associated with a sandy, paler clay and a darker, iron-rich clay. Because of its unusual deposition it is known locally as the 'clay amidst clays and the rock amidst rock'. Present-day firing temperatures used for I-hsing red stoneware average 1,200°C, which give porosities of about 10% in the fired material. All wares are still made by the hand modelling

[649] Li Zhuangda (1989), pp. 427–8.
[650] Thang Pai-Nien *et al.* (1992), pp. 389–405.
[651] Sun Jing *et al.* (1986), p. 87; Li Zhuangda (1989), pp. 424–9.
[652] Sung Po-Yin (1984), pp. 9, 12, 17, 21.
[653] Li Zhuangda (1989), p. 427.
[654] Sung Po-Yin (1984), pp. 9, 12, 17, 21.
[655] *I-hsing Ching-hsi Hsien Hsin Chih*, ch. 1 ('*Wu Chhan*'), p. 67.

Table 61 *I-hsing red stonewares: Northern Sung to Chhing dynasties*[a]

	Date	SiO_2	Al_2O_3	TiO_2	(FeO)	Fe_2O_3 (total)	CaO	MgO	K_2O	Na_2O	MnO	total
I-hsing stoneware	Northern Sung	62.5	25.9	1.3	(1.4)	7.75	0.4	1.36	1.4	0.07	0.1	99.4
I-hsing stoneware	Northern Sung	65.3	23.9	1.2	(3.1)	7.1	0.3	0.4	1.7	0.07	0.02	96.9
I-hsing stoneware	Northern Sung	64.9	24.1	1.2	(5.4)	8.2	0.3	0.3	1.3	0.07	0.01	95.0
I-hsing red stoneware	Early Chhing	64.6	20.7	1.3	(0.4)	8.6	0.5	0.55	2.5	0.13	0.02	98.5
I-hsing red stoneware	Early Chhing	71.0	17.3	1.3	(0.1)	7.2	0.3	0.4	1.7	0.1	0.02	99.2
I-hsing red stoneware	Middle Chhing	62.7	23.85	1.3	(0.3)	8.7	0.3	0.5	2.0	0.1	0.01	99.2
I-hsing red stoneware	Modern	60.7	23.4	1.15	(0.5)	9.95	0.2	0.6	2.85	0.07	0.02	98.4

[a] Sun Jing *et al.* (1986), p. 87.

and pressing of beaten clay slabs, and the micaceous red clay takes a subtle burnish from the finishing processes, often assisted with the use of buffalo-horn tools. A further patina on the red unglazed stoneware clay tends to develop with use.

CHI-CHOU WARE 吉州窯

Continuing on the tea theme, the last clay-type to be described in this section of the book is the material used to make Chi-chou wares in Chiangsi province. Chi-chou was another major site for tea-bowl making in south China, though tea-bowls were far from being the only products of this enterprising kiln-complex. The kilns at Chi-chou (also called Yung-ho 永和 in Chinese publications) were large-scale folk kilns in Chiangsi province. They seemed to have made whatever ceramics would find a market, borrowing styles freely from other areas of China. The kilns were operational from the early Northern Sung dynasty, reached a peak of production in the Southern Sung, and disappeared after the Yuan dynasty, when some disaster appears to have struck the area.

Chi-chou started by making celadons and *chhing-pai* porcelain, but then concentrated on blackwares enhanced with lighter-coloured ash-rich glazes. Also made at this site were Tzhu-chou-type decorated ceramics, poor-quality white porcelains some having reserved decoration, a few lead-glazed wares, and even some early southern overglaze-enamelled wares.[656] Chi-chou bodies varied in quality and colour, depending on the degree of clay preparation and the firing atmosphere; microstructural examination showed that some pieces were fired in reduction and others in weak oxidation, depending on their position in the kiln. The firing temperature was quite low (*c.* 1,200–1,240°C) and the range limited, for outside this range colour and designs did not mature successfully. Wares were generally slipped, and twice fired.[657]

Painted wares bore some resemblance to Tzhu-chou pots from north China. Blackwares sometimes had phase-separated glazes, in pale imitation of Chien ware, or two layers of contrasting glaze, or calligraphic sketches painted in white slip. The splashed and phase-separated glazes were given colourful names similar to those used for Chien wares by connoisseurs: 'tortoiseshell' (*tai-mao* 玳瑁), 'hare's fur', 'oil spot', etc. These dramatic effects depended on glaze layers having different compositions, the bottom layers appearing black and the surface layer yellowish. A great hallmark of the kilns was the use of resist decoration, either spots that left blurred glaze runs resembling tie-dyed textile, or papercuts, or leaves. Leaves were probably left *in situ* during firing so that they burnt away and turned to ash, while papercuts were applied to resist the second glaze application, then peeled away before firing to leave an outline impression. The resist outlines were highlighted by uneven

[656] Hughes-Stanton & Kerr (1980), pp. 51–4, 141–3.
[657] Au Jingqiu & Xu Zuolong (1985).

distribution and local concentration of the lighter-coloured ash-rich top glazes as the two glazes matured and interacted during firing.[658]

Chi-chou ware was popular ware, and bore few identifying marks save good-luck wishes. Saggers have been found bearing the names of local potter families (Tseng 曾, Chu 朱 and Yin 尹), and one sagger bearing a date equivalent to +1273.[659] Later connoisseurs were quite complimentary about the pots and included information about Chi-chou potters called Shu 舒. The *Ko Ku Yao Lun* (Essential Criteria of Antiquities, +1388) commented that:

> The body is thick and coarse in substance . . . In the Sung dynasty there were five kilns in Yung-ho 永和, Lu-ling county 盧陵縣, among which Master Shu 舒公 produced the most commendable white-and-brown wares. Big vases fetch several taels of silver, while smaller vases were decorated with delightful designs, and very good crackled ware was also made . . . Later, the kilns stopped production. The kiln site can still be seen, though houses have been built over it.[660]

Chu Yen elaborated on the subject in his compilation *Thao Shuo* (+1774):

> In the Sung period in Chiangsi province . . . one Shu Weng 舒翁 was good at making ornamental pieces. His daughter, called Shu Chhiao 舒嬌, was even better and their incense burners and vases were of equal quality in colour and design to Ko ware . . . today many potters at Ching-te-chen originally came from Yung-ho.[661]

CHI-CHOU WARE CLAYS

The clays used for Chi-chou wares supplied tough, light-firing bodies, but they do not fall readily into any particular Chinese clay category. For example, the Chi-chou clay is a high-flux material derived from impure porcelain stone, like many southern stonewares. But it is also a relatively high-alumina material, like most northern stonewares and porcelains (Table 62).

In fact the only clays comparable with Chi-chou wares, in this unusual combination of high alumina and high potassia figures, are the feldspathic Hsing wares of the Sui-Thang era. Nonetheless, when the 'titanium razor' is applied, the two groups can be effectively separated, and this explains why Hsing wares are pure white and translucent while Chi-chou wares are opaque and putty-grey. The high flux levels in Chi-chou wares gave unusually dense materials when fired, which makes tea-bowls feel heavy for their size. The refining of the original clay-like material seems to have been somewhat cursory at Chi-chou, as many wares contain fairly large grains of quartz. Firing temperatures in the typically southern dragon kilns used at Chi-chou averaged about 1,220° ± 20°C, and the kiln atmospheres used were 'weakly reducing'.[662]

[658] Au Jingqiu & Xu Zuolong (1985); Zhang Fukang (1985b); Chang Fu-Khang (1986); Hu Xiaoli (1992).
[659] Feng Hsien-Ming *et al.* (1982), p. 270.
[660] *Ko Ku Yao Lun*, ch. 3, p. 39b. David (1971), pp. 143, 306.
[661] *Thao Shuo*, ch. 2, pp. 9a–b.
[662] Au Jingqiu & Xu Zuolong (1985), p. 58.

Table 62 *Chi-chou ware clay bodies compared with feldspathic Hsing wares*

	Date	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Total
Chi-chou clay body[a]	Southern Sung	61.85	27.8	1.15	0.9	0.1	0.3	5.8	0.4	0.01	0.2	98.5
Chi-chou clay body	Southern Sung	62.6	27.4	0.1	1.6	0.01	0.3	6.4	0.3	-.-	0.2	99.3
Hsing feldspathic[b]	Sui-Thang	65.8	26.8	0.2	0.3	0.4	0.2	5.2	1.0	.01	0.06	100.0
Hsing feldspathic	Sui-Thang	62.9	26.9	0.2	0.4	0.5	0.3	7.3	1.6	-.-	0.01	100.1

[a] See Zhang Fukang (1985b), p. 59, plus data used from unpublished poster-paper.
[b] Chen Yaocheng *et al.* (1989), p. 224, table 2.

SUMMARY OF PART 2: 'CLAYS'

In Part 2 several important themes are identified. In the first instance, we stress that in many cases very similar clays were employed for making very different wares throughout China's history. As local sources of clays and rocks were gradually worked out at some Chinese kiln-sites (for example at Ching-te-chen) Chinese potters were obliged to look further afield for their ceramic raw materials. However, early kiln sites in China tended to grow and flourish near to local clay deposits, with water transport and fuel supplies being two further influences on their establishment.

Secondly, we note the unusually direct use that Chinese potters could make of their local materials, after suitable refining but often with surprisingly little modification or mixing. They were extremely adept at using single raw materials for a number of very different ceramic purposes, particularly through the manipulation of kiln atmospheres and firing temperatures. It is only recently, through chemical and microstructural analysis of the ceramics concerned, that these underlying connections have been made, as the objects resulting from this approach may look entirely different in their outward appearances.[963] Thus, for example, wares made from the same loessic clays include Neolithic burial urns from Kansu province; some thrown, turned, polished and carbonised Neolithic blackwares from Shantung province; the First Emperor's buried army, near Sian in Shensi province; and lead-glazed Han dynasty tomb wares from Honan province.

The classic stonewares of the Sung dynasties, and the later porcelains of Ching-te-chen, have helped to form our image of Chinese ceramics, but the subject embraces rather more than stoneware and porcelain vessels. For example, some of the most remarkable and complex ceramic constructions in China were the multiple-section ceramic piece-moulds used as an intermediary stage in Chinese bronze-casting. These were discarded in their thousands at Bronze Age casting sites, such as Hou-ma 候馬 and An-yang in north China, but represent one of the

[963] Wood (2000a), pp. 15–16.

most sophisticated examples of precision ceramic construction in history.[664] Ceramics were also important in China for metal-smelting, where they were used as refractories for furnace-bricks and crucibles, while in Chinese ceramic workshops kiln-bricks, saggers, setters, spurs, shelves, and bearings for wheels, were all made from earthenware, stoneware or porcelain, and were all essential for the successful operation of the industry.

In Chinese alchemy, ceramics were used for making stills and alembics, while some military uses for ceramics included the manufacture of pottery bomb- and mortar-cases, porcelain shrapnel,[665] and large jar-shaped listening devices for detecting sounds of digging around besieged cities.[666] In the peaceful arts, ceramics have always been important in China for the manufacture of musical instruments, and these range from earthenware pipes and drums in the Neolithic period to glazed stoneware lutes in the Sung dynasty, and refined porcelain flutes and zithers in the Ming and Chhing dynasties.[667]

Ceramic sculpture has also been a consistent theme in China, from the extraordinary life-size Neolithic clay figures with applied turquoise eyes from the Neolithic site of Niu-ho-liang (see pp. 5–6), through more than 7,000 terra-cotta warriors guarding the tomb of the First Emperor near Sian, in Shensi province. More than thirteen centuries later, during the Liao dynasty, Chinese potters created life-size glazed sculptures of mediating *lo-han* 羅漢 that are masterpieces of portraiture as well as of construction. The manufacture of architectural ceramics was also a major industry in China, where the products ranged from ordinary land drains to the most elaborately modelled and glazed roof ornaments. Even the massive grey blocks used for constructing substantial stretches of China's Great Wall were made from fired clay.[668]

The position that porcelain occupies in the history of world ceramics gives its interpretation a special significance. Although this material first emerged in north China, a proper understanding of northern porcelain, both within China and without, has been slow to form. The essential features of southern porcelains were well understood in +1900, but it was not until the First International Conference on

[664] For a detailed study of Hou-ma, see Anon. (1996), Institute of Archaeology of Shanxi Province; for An-yang see Watson (1971), pp. 70–81; Chang Kwang-Chih (1980a), pp. 98–9, 126.

[665] See Needham *et al.* (1986) for accounts of porcelain shrapnel being used at different periods in China: p. 163 +11th century; p. 232 +14th century; and p. 180 +17th century.

[666] Hollow objects described as 'pottery cannon balls', with short rounded spikes and dating from the Yuan and Ming dynasties, are displayed in the National Museum of Chinese History, Peking. Anon. (1988a), National Museum of Chinese History, p. 147, fig. 8-3-7. However, Needham *et al.* (1986), p. 46, fig. 4, describe these objects as 'naphtha or Greek Fire containers'.

[667] Six flutes made from the wing bones of cranes dating to *c.* –6,000 have been found in the Phei-li-kang culture 裴李崗文化 site. Zhang Juzhong *et al.* (1999), pp. 336–68 and Hua Lianlun (1988), p. 42. See also Anon. (1998a), National Museum of Chinese History, p. 19, fig. 2-2-6. A ceramic flute of the same style has been found at the Pan-pho 半坡 site. Chao Wen-I & Sung Pheng (1994), p. 78. A Sung dynasty ceramic lute, of purplish-brown stoneware, and perhaps from Kuangtung province, was once in the Palace Museum, Peking. Kuo Shi-Wu (1929), pp. 218–21. For a Te-hua porcelain *chhin* 琴 zither (possibly a model because of its small size) and a Te-hua porcelain flute, both made in the +17th century, see Ayers (2002), pp. 71 and 72, pls. 22 and 23.

[668] Zhang Zizheng *et al.* (1986), pp. 113–16.

Ancient Chinese Pottery and Porcelain was held in Shanghai in +1982, that the subject of northern porcelain at last came into focus, and the family likenesses between Kung-hsien, Hsing and Ting wares were finally established.[669] One of the many curiosities of this subject has been the growing awareness of the strong (but entirely coincidental) connections between the best northern porcelains and the pioneering hardpastes of continental Europe. Northern porcelain was remarkable for its body-material while, by contrast, northern stoneware relied on its glazes for a range of remarkable celadon wares such as Yao-chou, Ju, Chün, and also numerous fine blackwares. From relatively late beginnings in the +6th century, northern stonewares developed to put forth a magnificent flowering during the Sung dynasty.

Although south Chinese porcelain was some 300 years later in its emergence than the northern material, it has become the porcelain-type most closely identified with China. The pre-eminent centre for porcelain manufacture and export was Ching-te-chen in Chiangsi province, a city whose rich economic and political history embraced close links with the imperial court, and whose geographical location was occasioned by rich deposits of porcelain raw materials, and good lines of communication for the import of fuel and the export of its products. We discuss the use from the +10th century of a body-material composed solely of kaolinised porcelain stone, and its development to include admixtures of clay-rich materials and kaolin, in ever higher proportions. At another important kiln centre, Lung-chhüan, slightly higher iron oxide contents in local kaolinised porcelain rocks were often further enhanced by additions of iron-rich clays. Still darker bodies were used in the manufacture of southern Kuan ware, and also to make a range of teawares in south China.

[669] See particularly Li Jiazhi *et al.* (1986b), pp. 129–33, and Li Guozhen & Guo Yanyi (1986), pp. 134–40.

PART 3: KILNS

NEOLITHIC BONFIRE KILNS, UP-DRAUGHT KILNS AND REDUCTION-FIRING

BONFIRE-FIRING

In Part 1 of this book the underlying principles of firing were described, with reference to the baking of pots in a pre-formed, walled structure i.e. a kiln. The simplest method of firing, however, is to heat artefacts in an open fire. This system was and is used world-wide, in both ancient and modern cultures. 'Bonfire-' or 'open-' firing involves setting the wares on a bed of fuel, with more fuel placed between the vessels and surrounding the whole mass built to make a low mound. The fuel is ignited and allowed to burn fiercely until it is exhausted, by which time the wares are fired. The whole firing process may take less than an hour, and sometimes as little as twenty minutes.[1]

It may seem that bonfire-firing is a hazardous procedure. It does not seem to allow a 'water-smoking' stage, and provides precious little protection in cooling. Firing temperatures are often barely sufficient to achieve fired clay, and the wares are consequently weak. One great advantage of the method, however, besides its speed and economy, is that it can produce ceramics that are fireproof. In other words, the process results in vessels that can be placed directly on the flames of a cooking fire without cracking. This is largely because the high porosities and the loose structures of such low-fired materials accommodate well to the expansions caused by sudden heat.[2]

In practice, the dangers from this open-firing technique are more apparent than real. For example, the pots are usually thoroughly pre-heated before they are set in the 'bonfire', so they can easily survive the sudden rise in temperature when the fuel is lit. Also the wares tend to be heavily tempered with materials such as crushed fired sherds, or shell, or mineral grit, which serve both to 'open' the clay for steam release, and also to lessen the amounts of clay substance that need to be fired. The quantities of fuel tend to be judged nicely to fire the wares, and the vessels are often covered with layers of broken sherds, which provide protection from draughts in cooling. In many cultures grasses or reeds are thrown on to the burning bonfire at the height of the firing. Their bulky, siliceous ash provides some insulation in cooling, as well as sifting down between the pots, where it assists with firing as it burns.

[1] Rice (1987), p. 157. Tobert (1982), p. 236, pl. 3b, publishes graphs of bonfire-firing in late +20th century Sudan, that show the process may take twenty minutes to reach temperature on a windy day, but nearly sixty minutes on a calm day.

[2] Cardew (1969), p. 77.

Damage from quartz-cracking tends to be minimised by making the lower parts of the vessels rounded rather than flat, thus avoiding sharp angles towards the base. The low fired-strengths of the wares (mainly derived from sintering) are often supplemented after firing by splashing the wares with a glue-like mixture while they are still hot. This apes the role played by body-glass in higher-fired ceramics, and can improve both handling-strength and resistance to water; post-firing treatment with sealant liquors is often used for vessels intended for brewing.

EARLY CHINESE 'BONFIRED' WARES

It is a well-known problem in archaeology to distinguish ancient areas used for bonfire-firing from ordinary domestic hearths, though the excavated ceramics themselves may provide some clues to the bonfire process.[3] Signs of bonfire-firing include the heavy tempering of the clay, often with shell, grog or mineral grit, and the use of rounded bases on the wares. Blackened or patchy areas on the wares, pronounced black-core, and the lack of interstitial glass in the fired-clay structures, may also be indicators (although not proof) for open-firing methods. Suspected open-fired wares in China are those from Palaeolithic sites such as Hsien-jen-tung 仙人洞 (from strata dating to *c.* –8,820) and at Tseng-phi-yen 甑皮岩, Kuangsi province (from levels dating to *c.* –7,500 to –5,650).[4]

Bonfire-firing is sometimes the preferred technique in China, even today when conventional kilns are available. The advantages of the process lie in the speed, economy and simplicity of its action, and in the way that it can produce wares suitable for direct use on cooking-fires. Open firing was still practised in Kho-lai-sai 科莱寨, Yunnan province, by the Wa nationality 佤族 in +1977, despite true up-draught kilns being used locally.[5] At this site pre-heating of the wares was general, and sticky liquors were sometimes applied to the fired wares for the sake of extra strength and impermeability. The firings were relatively fast. In one case firing was measured as reaching 900°C in two hours, while in another 850°C was reached in one hour. However, when time-temperature relationships are borne in mind, which are particularly relevant at these low temperatures, 100–150°C should be deducted from the figures to represent equivalent firing temperatures in conventional kilns. The reports on these kilns are worth quoting in detail, as they may well have parallels with early firing methods used elsewhere in China:[6]

[3] Sites used for bonfire-firings may become indistinguishable from ordinary hearths after only a few years. For examples, see the experiments reported by Gibson & Woods (1990), pp. 27–30.

[4] Reviewed in Li Jiazhi *et al.* (1995), pp. 1–2.

[5] Cheng Zhuhai *et al.* (1986), pp. 27–34. Pool (2000), p. 61, writing about Mesoamerican kilns, observes a similar situation: 'In some cases, however, both kiln and non-kiln-firing methods coexist. These serve to remind us that the advantages of kilns are not absolute.'

[6] Cheng Zhuhai *et al.* (1986), pp. 31–2.

The Wa nationality at Kelai [Kho-lai] use wood as the fuel. They place the green wares on the firewood on the ground, and fire to dry the green wares. After drying they pile up more wood in a conical shape around the greenwares which are still hot and fire again. The whole process needs only two hours. As measured by a thermocouple, the maximum temperature attained is about 900°C. One firing requires 150 kilograms of firewood and can fire a total of 30 pieces of average size wares . . . For wine jars, shellac is coated both inside and outside to make them more durable and impermeable to water. The Dai [Tai] nationality 傣族 at Manhe [Man-ho] 曼賀, Mange [Man-ko] 曼各 and Manzha [Man-cha] 曼乍 villages mainly use straw and chopped wood as fuel. They put straw on the ground as the first layer, chopped wood as the second layer, and then the green wares, on and around which a layer of straw about 30 centimetres thick is laid . . . In the course of firing it is necessary to add more straw where the green wares are exposed. After one hour of firing, the temperature rises very quickly to around 850°C. Then it is allowed to cool. One firing requires 100 kilograms of straw and chopped wood and can fire 150 pieces of average size.

The use of shellac to condition wares for impermeability recalls similar practices used for Chinese domestic wares from early times. For example, *Chhi Min Yao Shu* (+533–544) described the waterproofing of storage jars after removal from simple kilns. The vessels were placed upside-down over a shallow pit containing burning charcoal and then inverted to allow hot lard to be swirled around the interior. Ox and sheep lard were recommended, though pork fat was also acceptable, whereas hemp oil was not viscous enough.[7]

At another stockaded village in Yunnan province the Tai nationality were in +1977 using a developed bonfire system, with firewood and corncobs placed beneath the pots, and straw set on and around the wares. However an important extra detail at this site was a one-centimetre thick layer of mud that coated the straw covering the wares. This gave a shell-like roof to the whole setting. When the fire was started several holes some three centimetres across were pierced in the clay cap to serve as exit flues. The firing was controlled by 'changing the number and location of the gas outlets, or lifting part of the covering from the ground to let the air in'.[8] In this case the firing took nine hours to a maximum temperature of 800°C, which is nearer to a true kiln's firing cycle. Use of this technique also permitted a far slower initial heat rise. This is shown in Figure 58, which is derived from readings from the three thermocouples set to record the firing.

Perhaps the most significant aspect of this 'developed' bonfire design is that it allowed a control over temperature-rise comparable with many simple up-draught kilns. Few traces of these thin clay-domed kilns would have survived at ancient sites, as their floors are quite flat.

Simple permanent kilns were also operating in this same area of Yunnan province in +1977. One example (at a second stockaded village operated by people of the Tai nationality) seems of cross-draught design. It is essentially a shallow depression

[7] *Chhi Min Yao Shu*, ch. 63 ('*Thu Weng*'); Shih Sheng-Han (1981), pp. 446–7.
[8] Cheng Zhuhai *et al.* (1986), p. 32.

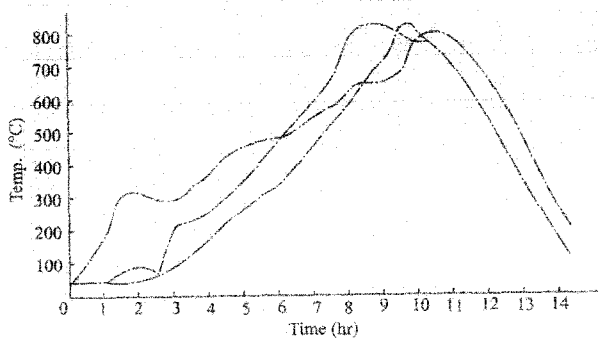


Fig. 58 Firing cycle from a Tai nationality stockaded village kiln, Yunnan province, late +1977

in the ground (1.3 metres in diameter) into which two parallel horizontal tunnels ran. The wares were set within the well and the fires burned in the tunnels:[9]

When the firing temperature reaches 600–700°C, the potter puts some straw to seal the kiln top and cover all the vessels. The straw ash has the function of preserving heat. The firing ends when the temperature reaches 800°C. The whole firing process takes about two hours.

This again shows how caution should be used in making assumptions from the microstructures of ancient wares, as ceramics from this firing would show body characteristics typical of bonfire-firing, despite being the products of a true permanent kiln. Also the kiln design is non-up-draught, with the fires and the wares set horizontally in line. What this design *does* represent is the vital capacity to add extra fuel while the kiln is firing thereby, potentially, providing both better control of the temperature rise, and also the duration of the firing. A bonfire-firing by contrast has to be 'programmed', by placing the correct amount of fuel beneath and around the wares. Extra straw is added on top, not to aid firing but to better protect the wares from cold draughts.

Taken together, these +1977 studies in Yunnan province provide some salutary lessons in the interpretation of ancient sites. They not only show the degrees of variety possible with open-air (bonfire-)firing techniques, but they also demonstrate the amount of control that can be introduced to the bonfire process through the use of thin temporary clay domes. The studies also demonstrated that permanent kilns with separate fireboxes, to which fuel can be added (often considered the next step after bonfire methods), may behave just like bonfire kilns in their rates of firing, and in the low temperatures that they reach. They also raise the possibility that cross-draught structures, with fireboxes and combustion areas on the same level, might even pre-date true up-draught kilns, where the fire burns beneath a perforated

[9] *Ibid.*, pp. 32–3.

floor. It is also interesting that none of the structures described in this paper can be called a pit kiln. A pit kiln is an arrangement whereby ceramics are fired in shallow pits, which shield the wares somewhat against draughts, and also protects them in cooling.

Pit-firing is often considered to be a development from bonfire-firing, although Kato Eiji 加藤瑛二 questions this theory with regard to China, and suggests that local geography and culture may have had more influence on whether bonfire or pit-firing methods were adopted.[10] In support for this idea he cites the area where Tibet borders both northern Yunnan and western Szechuan provinces. This district still contains a mixture of open-firing and pit-firing traditions that seem to depend mostly on local terrain.

True Ceramic Kilns

With regards to the remains of very early true permanent kilns in China, the easily excavated loessic silts in north China have proved the richest source, both for the construction of the kilns and for their survival. Nonetheless the very earliest proposed examples of northern Neolithic kilns still present some problems in interpretation. For example, there is the rather puzzling structure, claimed as China's earliest excavated kiln, at an early Neolithic Phei-li-kang 裴李崗 culture site in Honan province, and dated to –6,000 to –5,700 (Fig. 59).[11]

The round base of this feature was some 0.8 metres across inside, and showed a burned layer some ten centimetres thick. An odd aspect of the structure was five semi-circular depressions 6–8 centimetres in diameter in the base of the low wall, opposite the 'flue' (see plan). Neatly made round-bottomed bowls and jars with three stubby feet were typical ceramic productions of this district, and these reddish wares seem reasonably well oxidised. Other finds from this Phei-li-kang site (some 75 kilometres south of present-day Cheng-chou 鄭州) included some finely made sickle-stones with small serrated teeth.

However, the five curious depressions in the base of the structure's wall, opposite the 'flue', may suggest another use for this feature, namely that it was a cooking-hearth rather than a kiln. Similar 'keyhole-'shaped structures with low walls have been excavated at the Yang-shao culture 仰韶文化 site at Pan-pho 半坡, where they were sited in the centres of large huts.[12] One example had a pot permanently placed inside the low wall, next to the fire-area, apparently to hold live cinders. If this were removed it would leave a semi-circular depression, similar to those on the

[10] Kato Eiji (1999), pp. 508–13.

[11] Anon. (1979c), pp. 197–205; see also Anon. (1993), Institute of Archaeology, Chinese Academy of Social Sciences, pp. 5–6. However Li Yu-Mou & Chhen Hsü (1979), p. 349, write: 'There are three radio carbon dates obtained from pieces of charcoal at Phei-li-kang: 5,935 ± 480 BC, 5,195 ± 300 BC and 7,350 ± 1000 BC. Because of error due to the small sample and combination testing the figure of 7,500 BP [–5,550] is probably more reliable.'

[12] Watson (1960), pl. 7. The hearth's diameter can be assessed at about 0.8 metres.

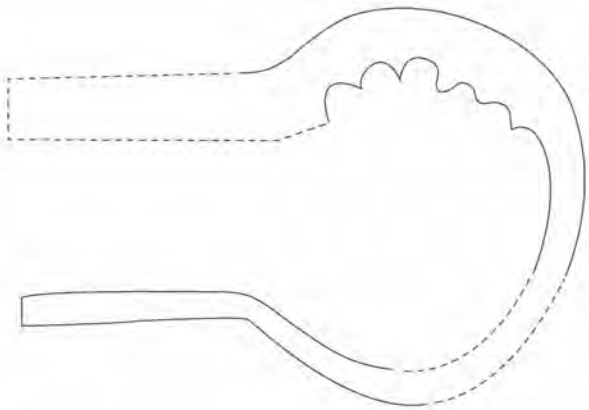


Fig. 59 Plan of the Phei-li-kang culture structure in Honan province.



Fig. 60 Remains of a Yang-shao culture hut at Pan-pho, showing central fireplace and large sections of the collapsed roof (lighter material). The hearth's diameter is about 0.8 metres

Phei-li-kang structure. Another explanation for these depressions might be that they were impressions from hearthstones, which have also been found in some northern Chinese Neolithic sites. The Phei-li-kang structure is therefore not unequivocally a pottery kiln, although, conversely, there is no reason why some early kilns should not have taken on some hearth-like forms or features.

EARLIEST CHINESE NEOLITHIC WARES

Although extremely ancient, the Phei-li-kang culture vessels are not the earliest ceramics found in China. Earlier pieces have been found at Nan-chuang-thou 南莊頭 in Hopei province (*c.* –8,550 to –7,750); Hsien-jen-tung in Chiangsi province (*c.* –7,050 to –5,650, i.e. the mid-period for the whole site continuum); and Tseng-phi-yen in Kuangsi province (also *c.* –7,050 to –5,650).[13] So far no kilns have been found associated with these finds, as Li Jiazhi (Li Chia-Chih 李家治) *et al.* point out:[14]

> Of course it can't be affirmed that there were no pottery kilns at that time despite not having found pottery kilns . . . The crystalline microstructures of hornblende and muscovite were well preserved, so it can be known that the firing temperature was between 600–700°C . . . greatly lower than the real firing temperature (820 to 920°C) of the pottery fragments of Peiligang [Phei-li-kang].

If the Phei-li-kang structure were a kiln, the separation of the fuel-burning area from the ware-setting area would have been an essential feature of the design, and a substantial aid to firing control. Yet another possibility is that this was a 'boosted-bonfire' type of kiln, similar to the modern kiln in Yunnan province described above. If this were the case it would not have been quite an up-draught kiln, unless the wares were raised from the kiln floor through some arrangement now lost.

EARLY NORTHERN UP-DRAUGHT KILNS

One way to improve kilns of the style described above would have been to make some channels in the kiln floor, to direct some flame beneath the wares. This approach can be seen at a Yang-shao culture site in Honan province. This area has seen numerous successive occupations, and was an important site for both Neolithic and early Shang dynasty societies. The firebox for the Lin-shan-chai 林山砦 kiln is lower than the kiln-chamber, and deep branching channels in the kiln's floor helped spread the flames towards the outsides of the ware-setting.[15]

A better arrangement for up-draught kilns is where the fuel burns in a cave-like space at a level lower than the wares, and the flames rise through a perforated floor into the firing chamber where the wares are set. Up-draught kilns of this style are

[13] Cited in Li Jiazhi *et al.* (1995), p. 1.
[14] *Ibid.*, p. 4.
[15] Feng Hsien-Ming *et al.* (1982), p. 8.

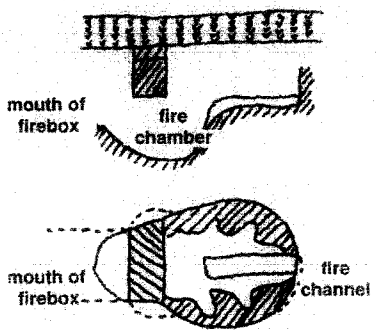


Fig. 61 Lin-shan-chai Yang-shao culture kiln, Honan province

seen in a well-preserved state at Pan-pho. The Pan-pho site is not only rich in kilns, but it also provides one of the most vivid images of Chinese Neolithic life yet established (see pp. 3–5). Six kilns have been excavated, as well as hundreds of pottery vessels and fired-clay objects. The large museums at Pan-pho accommodate some of the 10,000 artefacts uncovered during excavation.

Ceramics from Pan-pho are particularly sophisticated, and include earthenware rings, spindle-whorls and large fired-clay sockets used to support hut-posts. Even ceramic flutes have been discovered that produce a sound 'very much like the music in Chhin opera' (秦劇, the local opera of Shensi province).[15] Many vessels show a fine sense of form and the use of smooth materials. None is thrown on a fast wheel, but the hand-building skills are sure and accurate and may have been assisted by the use of a slow wheel made from ceramic (see pp. 388–90). Some vessels are painted with fired-on iron- and iron-manganese pigments to give stylised patterns of deer, fishing nets, fish and human faces, as well as bold abstract patterns of chevrons and triangles. Abstract sgraffito marks, carved through the slip on some vessels, have been interpreted as a form of primitive writing, while pottery steamers made in three parts supply evidence for sophisticated steam-cooking methods.

The kilns at Pan-pho were grouped towards the east of the site, perhaps so that prevailing winds took smoke away from the village.[17] They are of true up-draught design with firebox, flues and firing chambers clearly defined, constructed and separated. The interiors of the kiln-chambers were some 0.75–1 metres in diameter and the firing temperatures have been estimated at some 800–1,000°C. All the kilns' superstructures are missing.[18]

[16] Chao Wen-I & Sung Pheng (1994), p. 78

[17] The general south-eastern spread of loess across north China, from its origins in the north-western deserts, suggests this view.

[18] Chao Wen-I & Sung Pheng (1994), p. 24.

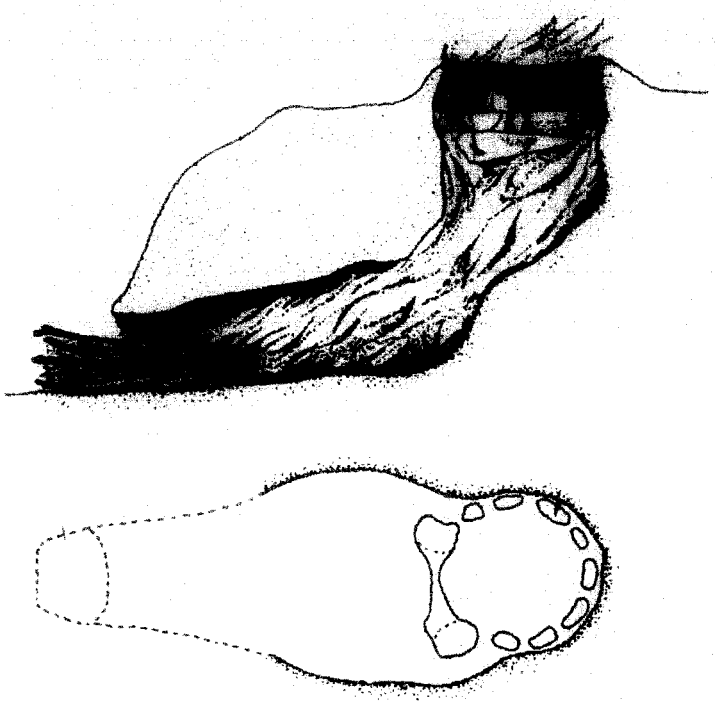


Fig. 62 Pan-pho kiln (earlier type)

The kilns at Pan-pho were of two styles. The earlier consisted of a tilted tunnel for burning the fuel, about two metres long, excavated, or 'cut and covered' into the loess from a shallow pit where the fireman stood. The higher end reached ground level and led into the round kiln-chamber through a solid floor perforated with vertical slots. The kiln-chamber was about one metre in diameter inside.

The long and nearly horizontal fireboxes allowed a small fire to be set well away from the wares at the dangerous stage at the beginning of the firing. The full combustion space was still available later to develop the major heat needed to fire the wares. Evenness of temperature within the kiln was managed by exploiting two important principles. First, the slot-shaped holes in the kiln floor (between the combustion chamber and the wares) were made larger, or more abundant, both towards the floor's perimeter and also towards the back of the kiln. Second, the total area of these fire-channels was kept small, typically to one-tenth of the floor's total area.

The first effect thwarted the tendency of the fire to 'chimney', that is, to find the centre of the setting at the expense of the outer pots (this 'chimneying' phenomenon, where flames find the centre of the fire, is often seen with fiercely burning

bonfires). By forcing most of the fire to the outside, these holes created a 'ring of fire' within the kiln, rather like the flames of a domestic gas-ring. This meant that the outer pots in the kiln were well fired by direct flame, while wares nearer the centre were also well fired, both through direct heat and also from conduction. The kiln acted as its own chimney (hot air being less dense than cold) and the combustion gases rose vertically through the wares.

The second feature (i.e. the low total area of the flame-channels leading into the kiln-chamber) slowed the flame-speed, conserved energy and fuel, and supplied more even heating to the wares. Slow cooling was managed by half-burying the kiln to provide good insulation, and probably also by covering the firebox opening when the kiln had finished firing. This is a classic up-draught kiln design, and has many parallels throughout the world, both before and after the -6^{th} to -5^{th} millennium period that the Pan-pho kilns represent.[19]

The second kiln-type at Pan-pho has been described as follows:[20]

> The vertical kilns that began to appear in the later period of Banpo [Pan-pho] were more advanced in structure than their precursors. A marked characteristic of the vertical kiln was that the fire passage was much closer to the kiln-chamber, shaped like a big bag with the fire chamber just below it. There were two big holes under the grate, which served as the fire channels. Generally speaking the kiln was larger in size than any of its forerunners.

Both designs would have worked well, but the later design would have needed more care in the very early stages of firing because the main combustion area was much closer to the wares being fired.[21]

SIZE OF FIREBOX

Chinese Neolithic kilns have rather small firing chambers, typically one cubic metre in volume or less. Excavation of the Pan-pho kilns suggests that as much space was used beneath the kiln floor to burn the fuel as there was space above to set the wares. These are typical firebox-to-chamber ratios for small wood-burning kilns and similar proportions are seen with a rather later kiln of the Lung-shan culture 龍山文化 at Miao-ti-kou 廟底溝 in Honan province.[22] The Miao-ti-kou kiln had a rectangular firebox (0.9 metres × 0.9 metres × 0.6 metres), while its kiln-chamber proper was probably roughly hemispherical (floor dimensions 0.9 metres × 0.8 metres).[23] This

[19] Large updraught kilns with similar perforated floors (1–2 metres in diameter) are known from Iraq. These are somewhat earlier than the Pan-pho kilns. See Simpson (1997), p. 39, fig. 2.

[20] Chao Wen-I & Sung Pheng (1994), p. 68.

[21] This change in kiln design at Pan-pho may relate to different occupation phases at the site. K. C. Chang, for example, proposes that the Pan-pho complex saw successive and interrupted rather than continuous occupation. This opinion was based partly on studies of pollen types typical of different periods: 'There is no question that both occupations were by people of the same culture, but minor changes in house construction methods and in artefact style are appreciable.' Chang Kwang-Chih (1963, 1986), p. 96.

[22] As Michael Cardew explains: 'Wood is a bulky fuel and burns much better in a big fire than a small one . . . In the case of a very small kilns a practical limit is soon reached for the dimensions of the firebox.' Cardew (1969), pp. 184–5.

[23] Yang Gen *et al.* (1985), pp. 16–17.

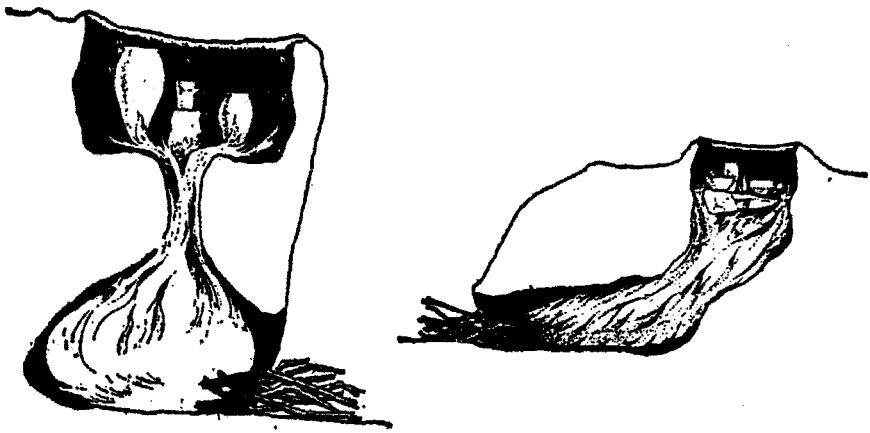


Fig. 63 Two styles of Pan-pho up-draught kiln

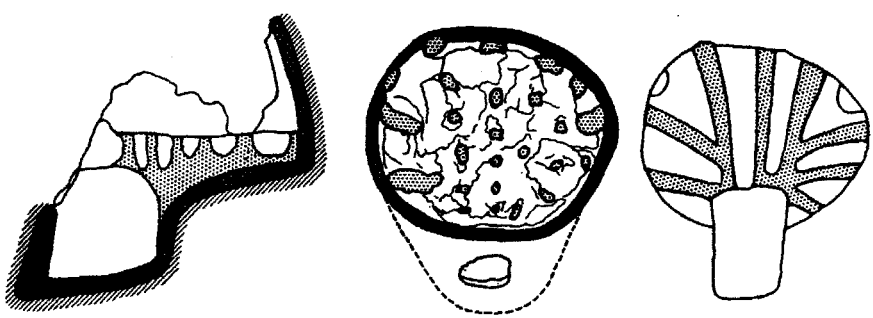


Fig. 64 Miao-ti-kou Lung-shan culture kiln. It can be seen how the branching flues beneath the kiln's floor have been selectively covered to direct the flames to the outside and to the back of the setting

would again have given a firebox and a kiln-chamber of about equal capacity. The Miao-ti-kou kiln also provides an excellent illustration of how the fireholes leading into the kiln-chamber were arranged to direct the flames to the back and to the outside of the setting. When the cross-sectional areas of these holes are totalled they also comprise about 10% of the kiln-floor area, a classic and common ratio for up-draught kiln designs world-wide.

KILN SUPERSTRUCTURE

Most Neolithic kilns excavated in China are missing any structures above the level of the kiln floors. Imaginative reconstructions by archaeologists often suggest domes

or other enclosed features above this level, particularly where any surviving walls curve inwards. These can be reasonable assumptions, but there is also the consideration that many early and traditional up-draught kilns are built 'open-topped' and without permanent roofs or enclosing domes. In these designs temporary domes were often built for each firing, or the vessels at the top of the setting were simply covered by layers of sherds. Both methods work well and control the draught sufficiently to stop the flame-speeds becoming wastefully high, while still providing sufficient insulation to prevent this part of the setting from being underfired and/or damaged in cooling. If the entrance to the firebox is well sealed after firing there are no cold draughts through the hot wares, and they are able to cool safely.[24] In short, one does not have to imagine that some permanent domed roof was always present on Chinese Neolithic kilns to complete their designs, although their absence at excavation does not prove that they were missing from the original structures.

If a permanent dome, or any kind of permanent roof, is constructed on a kiln it follows that the design should also include a doorway for setting and drawing the wares, and that this doorway must be large enough to admit the largest wares being fired. This adds substantially to the complexity of the kiln's design, and a kiln doorway ('the wicket') also tends to be a weak point in a kiln's structure. Exactly these features of dome and door can be seen in two unusually complete north Chinese Neolithic kilns found in Shansi province in +1997.[25] The kilns appear to have been hollowed directly into a loess bank, which would have simplified construction considerably. As the site was scheduled for a reservoir the two kilns were removed intact, for eventual reassembly.

The dimensions and structures of the two kilns are given in Figure 65. As with the other Lung-shan culture kiln in Figure 64, it appears as if a further perforated floor was placed over these channels, inside the kiln-chamber. That layer, which is now largely missing, controlled the ingress of flame. The diameter of the exit flue on the kiln coded Y501 measured some 0.3 metres, compared with the kilns' floor-diameter of about 1.5 metres, giving an area-ratio of 5:1.

The exit flue on kiln Y502 was less generous at 0.25 metres to 2 metres floor diameter, giving a floor-to-exit-flue ratio of 8:1. It is less easy to assess firebox-to-kiln-chamber volumes from the plans of these excavations, as both kilns have lost some of their firebox structures. Nonetheless, the fireboxes appear smaller than the kiln-chambers they serve, which is one of the 'economies of scale' inherent in kiln design.[26]

[24] Open-topped updraught kilns of this type were still in use in England in the +1950s at the Verwood pottery in Dorset, see Brears (1971), p. 148. One of the authors (RK) visited Reade's brickworks in Aldeburgh in July +2000, where an open-topped brick clamp was firing using oil. This kiln had replaced an older coal-fired model in +1964.

[25] Anon. (1998d), pp. 28–32. The *People's Daily*, 24 July 2000, reported the removal of these kilns to a point some 100 kilometres away from the reservoir project. The move took one year and cost Y300,000, partly borne by Fu-tan University 復旦大學 in Shanghai.

[26] As kiln volumes increase the ratios between the kiln-chamber-volumes and firebox capacities tend to increase markedly. See Cardew (1969), p. 185.

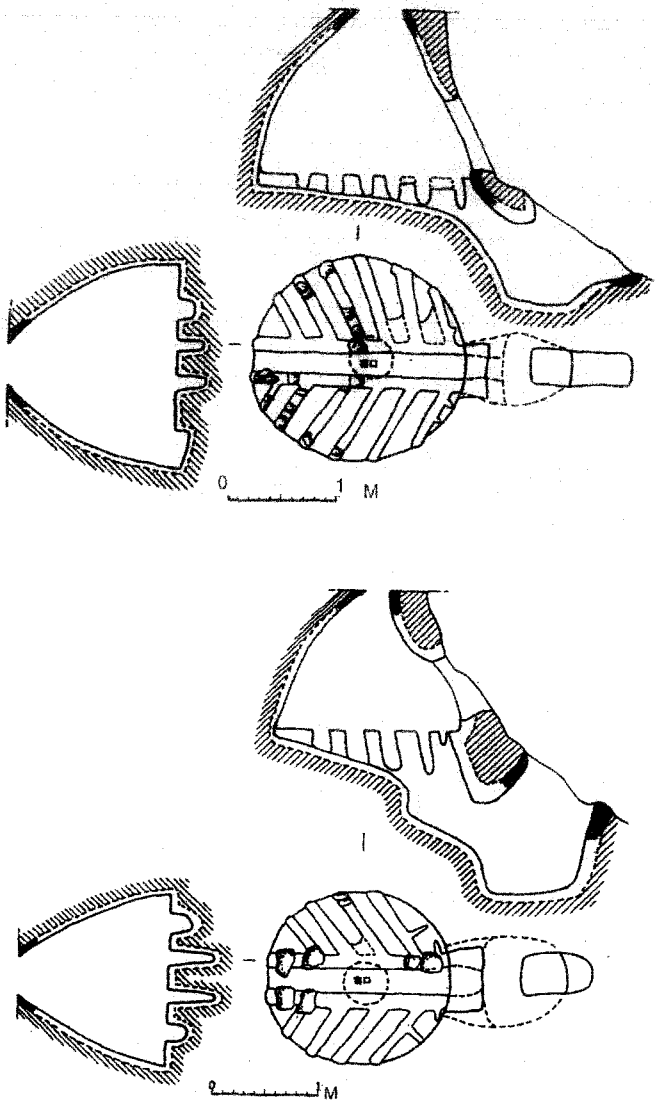


Fig. 65 Miao-ti-kou period II Neolithic kilns in Shansi province

OXIDATION, REDUCTION AND CARBONISATION

At the very beginnings of pottery production in China, during the Neolithic period, the colour of different wares was important. Many ceremonial items were reddish in colour, a result of firing in oxidation. Another important group of wares was grey and black, their colours attained by firing in reduction, and by carbonising, respectively. In essence, oxidation and reduction are chemical processes, often deliberately invoked during firing, usually by adjusting the amount of air that is burning the fuel. With plenty of air the kiln atmosphere is described as *oxidising*, with the main combustion products being carbon dioxide and water. By limiting the supply of combustion air some carbon *monoxide* (CO) appears in the combustion gases and this unstable compound 'steals' some oxygen from metallic oxides susceptible to this effect, and converts itself to the more stable state of carbon dioxide (CO_2). This loss of oxygen changes both the status and the colour of metallic colouring oxides. Thus Fe_2O_3 (red iron oxide) may become Fe_3O_4 (magnetic iron oxide) and then FeO (black iron oxide) as the reduction intensity increases. This changes iron:oxygen ratios within these compounds from 1:1.5, to 1:1.3, to 1:1. In pottery kilns the effect tends to terminate with FeO, although full reduction to elemental iron (Fe) was practised by Chinese smelters as early as the –8th century.[27] In most pottery kilns carbon monoxide serves as the main reducing agent, but in some ceramic traditions in China, hydrogen (an extremely powerful reducing gas) may have been generated towards the end of the firing through the introduction of water to the firebox or to the kiln-chamber. Hydrogen is a powerful reducing agent as it actively converts to H_2O.

Many Chinese ceramics from the later Neolithic period are grey or black. While the grey colours are caused by deliberate reduction-firing and reduction-cooling, the black effects must derive from the carbonising of the wares. Carbonisation is caused by impregnation with black smoke, either within the kiln, or during a later finishing process.

The Neolithic practice of reduction-firing red-burning clays to give a grey result seems to have been extended from clay vessels to architectural ceramics as early as the Shang dynasty,[28] since when grey reduction-fired bricks and tiles have become universal in China. It is only relatively recently (over the last twenty years or so) that the reduction-firing of architectural ceramics has become less popular in the country, with traditional grey bricks gradually being displaced by oxidation-fired (and substantially weaker) red ones. Given the antiquity and the continuity of this process, the possibility has been raised that surviving country brickyards in both the north and the south may preserve some clues to Neolithic practices in the production of grey wares.[29]

[27] Wagner (1999), p. 7.

[28] Zhang Zizheng *et al.* (1986), pp. 111–12. A grey pottery pipe dating to the Shang dynasty is described and its analysis quoted. It shows a typical loessic composition.

[29] Levine *et al.* (1995), pp. 170–1.

CHINESE GREY-BRICK PRODUCTION

Modern brick-makers in China use two distinct and different methods to achieve reducing atmospheres within their kilns, namely conventional 'air-starved fuel' reduction and, apparently, the generation of water gas. The former method was observed by the authors in Fukien province in +1995 at a tileworks on the road from Fu-chou 福州 to Te-hua 德化, where we arrived just as the up-draught tile kiln was reaching its reduction-stage of firing. To achieve reduction loose slabs were moved partially to cover the exit flues on the kiln's roof, which caused grey smoke to pour from the flues. This was obviously cutting down the draught at the kiln's firebox, and with it the air that was burning the fuel. This in turn must have provided the familiar mixture of carbon monoxide and carbon dioxide associated with inefficient combustion, an effect often accompanied by the grey smoke of unburned fuel. In this situation some carbon monoxide in the combustion gases tends to convert to carbon dioxide at the expense of some oxygen in the clay's ferric (iron (III)) oxide (Fe_2O_3), reducing much red iron oxide to its black, ferrous (iron (II)) state (FeO). This makes the tiles appear grey after firing. As iron (II) oxide is rather easily reoxidised, some degree of reduction must have been sustained through early cooling. However, there seemed no facility for the introduction of water at this kiln.

The second technique – the generation of water gas – has been proposed as having been used for brick-making in China as early as the +17th century.[30] *Thien Kung Khai Wu* (The Exploitation of the Works of Nature, +1637) says:[31]

> The green bricks . . . are placed inside the kiln and fired for one complete day and night for 3,000 catties [of bricks] . . . when the firing process is complete and firing halted, the smoke holes in the top of the kiln are sealed with mud and then water is used to quench the bricks . . . this is done by pouring water on to the level space on the roof of the kiln which is surrounded by a raised wall on all four sides. The water having permeated the earthen roof reacts with the heat. When the right proportion of water to heat is managed, then quality and durability are assured.

In practice, the generation of water gas involves bringing water and red-hot carbon into contact.[32] The water flashes to steam, and combines with incandescent carbon, to give hydrogen, carbon dioxide and carbon monoxide, from two possible reactions, both strongly endothermic:

$$C\,(s) + 2H_2O\,(g) \rightarrow CO_2\,(g) + 2H_2\,(g)$$

$$C\,(s) + H_2O\,(g) \rightarrow CO\,(g) + H_2\,(g)^{33}$$

The first reaction starts at 600°C (dull-red heat), while the second replaces the first above 1,000°C (orange heat). From 600° to 1,000°C both reactions occur,

[30] Levine *et al.* (1995), pp. 167–71.
[31] *Thien Kung Khai Wu*, pp. 3a–b; Sun & Sun (1996), p. 138.
[32] Singer & Singer (1963), p. 915.
[33] Cited in McMeekin (1984), p. 43.

although the first fades away as 1,000°C is approached. Both carbon monoxide and hydrogen are highly efficient in reducing iron (III) to iron (II) oxide,[34] although care has to be taken with the process, as mixtures of hydrogen with air can be explosive. Further production of hydrogen is also possible from the 'water-gas shift reaction'. This reversible effect comes from the reaction of carbon monoxide and water vapour at high temperatures:

$$CO\,(g) + H_2O\,(g) \leftrightarrow O_2\,(g) + H_2\,(g)$$

Water-Gas Reduction in Chinese Brick Kilns

It is still a fairly common sight in China, to see roadside grey-brick and grey-tile kilns with large water-jars or rectangular cisterns set on their roofs. Grey bricks and tiles have such firm associations with China, that:[35]

> archeologists and architectural historians have used the difference between Chinese grey brick and the red brick of West and South Asian peoples as a way of demarcating settlements in the western borderlands of China.

The firing process of one such grey-tile kiln was studied first-hand by Pamela Vandiver at a company producing roof tiles and bricks in Shanghai +1992:[36]

> The particulars of firing included reaching peak temperature then sealing up and claying over the firebox and the entrance to the flue, and finally introducing water into the kiln from a reservoir on the roof . . . The conclusion of this visit, as well as visiting old abandoned kilns and talking to engineers at northern factories where replication of the emperor Qin Shi Huang Di's [Shih-Huang-Ti, First Emperor of the Chhin 秦始皇帝] ceramic army is being carried out, is that reduction by hydrogen is necessary for at least some unglazed Han period ceramics, brick and tile products since Han period and perhaps some Neolithic ceramics, such as Lunshan [*sic* = Lung-shan] ware.

In order to establish some protocol for recognising hydrogen reduction in ceramics, a tile from the Shanghai factory was studied at the Ion Beam Materials Laboratory at Los Alamos National Laboratory, USA, using a technique known as Forward Recoil Energy Spectrometry (FRES). This method was able to:[37]

> differentiate between bricks that have hydrogen bound in the structure and those that have hydrogen only on the surface, as in the form of adsorbed water.

As to the larger question of whether FRES could identify hydrogen reduction in early Chinese ceramics, grey Lung-shan Neolithic wares included, the answer is perhaps less clear, as the technique may not be able to distinguish between the use

[34] As Levine *et al.* (1995), pp. 169–70, explain: 'Hydrogen is a common modern strategy for obtaining heavily reducing atmospheres. Consulting an Ellingham diagram or simple calculation shows that hydrogen atmospheres produce superior reduction to carbon atmospheres.'
[35] *Ibid.*, p. 169.
[36] *Ibid.*, p. 171.
[37] *Ibid.*, p. 177.

of water added to the kilns, and the accidental or deliberate use of wet fuel.[38] In short, it is not yet possible to demonstrate from analysis that hydrogen reduction involving the deliberate use of free water was practised for any Chinese Neolithic wares, nor indeed yet for any Chinese historical wares.

Other Possible Reasons for the Use of Water in Brick and Tile Kilns

Despite all the above, some caution should be exercised before assuming that water-gas reduction is involved in every case where water is used at the end of a firing. It is possible that rapid cooling may be another motive, as evaporation of the water would cause the temperature of the setting to fall rapidly through the range where reoxidation to a reddish colour might occur, i.e. from the kiln's finishing temperature to about 600°C. Indeed it seems possible that rapid cooling has at times been mistaken for water-gas reduction and, conversely, true water-gas reduction may sometimes have been thought to be mainly rapid cooling.

A possible example of this latter error occurs in one of Herman Seger's letters of +1872, where he describes the role of water at the finishing stages of some Lower Rhine and Belgian brick kilns.[39] Seger records that, at full temperature, the kiln fire-boxes were charged with green alder logs and the fire-holes and flues rapidly walled-up, thus filling the kiln with reducing gases and black smoke. Seger then describes the pouring of water over the kiln's vaulted arch, a process that he believed was intended to prevent reoxidation, and also to cool the kiln rapidly. To avoid any water running directly in the kiln-chamber (which might have caused an explosion) the kiln's arch was covered with eighteen centimetres of tamped sand. Seger writes that the water:[40]

> stands several centimetres deep on the arch and thus maintains a steady evolution of steam in the interior of the kiln, which prevents the admission of air.

In hindsight we can suspect that Seger may actually have been describing water-gas generation, particularly from the way that black smoke (particulate carbon) rather than reducing gases would have been produced by the green alder logs. The black smoke may have provided incandescent carbon and carbon monoxide for water-gas reactions. It is possible too that the rapid cooling provided by the water helped to stabilise and to preserve the effect. This in turn suggests one possible way that this unlikely process may have arisen in China, i.e. by the rapid cooling of a reduction-fired kiln with water to avoid reoxidation. The presence or absence of black smoke

[38] Pers. comm. with Pamela Vandiver in +1995.

[39] Seger (1900e), pp. 767–9.

[40] Seger, *ibid.*, p. 768, notes the superior strength of these reduction-fired bricks and tiles: 'The roofing tiles thus blue-smoked withstand weathering much better than the red ware, and for this reason the wise council of the city of Ghent has decreed that all roof areas fronting the streets must be covered with blue tiles, and the use of red tiles is permitted only for back buildings and the sides turned towards the yards.'

and/or carbon monoxide in the red-hot kiln immediately prior to the introduction of water or steam, would seem to dictate whether some water-gas was produced, or whether the kiln temperature simply fell rapidly. The latter occurrence could prevent unwanted reoxidation of reduction-fired wares and maintain their grey colour, while the former would generate or intensify it. Grey wares could therefore result from both processes, and it is not impossible that it was mainly rapid cooling, rather than hydrogen reduction, that was being described in *Thien Kung Khai Wu*.

Air-Starved Fuel Reduction and Carbonising

Reduction by water is a somewhat exotic process. Deliberate reduction-firings in most cultures seem to have involved the simpler method of starving the fuel of air to some extent. This causes some reducing gases (mainly carbon monoxide, but with a small amount of hydrogen) to pour through the kiln-chamber. The gases replace some of the usual combustion products, namely carbon dioxide and water, and reduce some iron (III) oxide in the clays to its iron (II) state. This may well have been the process used for most Chinese grey-fired Neolithic wares.

If the fuel in the kiln firebox is further starved of air, particulate carbon (i.e. C, black smoke) tends to replace the CO. Black smoke has little or no reducing effect, but can impregnate porous clays throughout their depths to give black rather than grey wares. 'Carbonising', as this process is called, does not rely on the iron-rich clays that are necessary for producing grey wares. Any clay, pure white kaolins included, will turn black with carbonising, which is both a clean and permanent effect once the wares are washed and dried. Carbon impregnation may also render the wares less porous.

Deliberate carbonising, as a decorative process, is familiar from Predynastic Egyptian 'black-topped' vessels. These may have been produced by using a post-firing method that set oxidised and red-fired wares rim downwards in some smouldering material (such as chaff), locally carbonising the tops of the vessels while leaving the remainders red. These are typical products of the Naqada I Predynastic culture (–4,000 to –3,600) from Hu and Mahasna in southern Egypt.[41] Chinese carbonised wares by contrast are black all over, which suggests that the style may have developed from earlier Neolithic greywares. The Chinese Neolithic carbonised wares from north China that have been analysed are of both kaolinitic and loessic compositions. They are typical of Ta-wen-khou 大汶口 culture sites in Shantung province and date from about –2,800 to –2,000. In style, they are exceptionally thinly thrown and turned, with complex and dramatic forms that include raised dishes with perforated tall feet, and goblets with finely perforated stems. These are some of the most remarkable of all Chinese Neolithic wares, although their black

[41] Arnold & Bourriau (1993), p. 95.

character was anticipated to some extent by wares of the Liang-chu 梁渚 culture of the Thai lake 太湖 and Hang-chou bay 杭州灣 area of southern China.[42]

LIANG-CHU CULTURE BLACKWARES OF SOUTH CHINA

Little mention has been made so far of southern Neolithic wares, as few Neolithic kilns have been excavated in the south. Nonetheless C^{14} datings show that southern Neolithic sites followed parallel developments to those in north China, with rice-cultivating areas in the lower Yangtze valley, the Thai lake valley and Hang-chou bay areas being important for their development.[43] Liang-chu culture blackwares are found in this latter district and take their name from a small town some 25 kilometres north-west of Hang-chou. Liang-chu blackwares are distinguished by their high carbon contents, though in this case their black colours derive largely from deliberate additions of organic material or charcoal to the clays before firing, relics of which can be seen in the fired wares. A study of two samples of Liang-chu blackwares made in +1992 revealed TL dates between −3,550 and −2,150, and firing temperatures of about 700 to 800°C. From studies of approximately 150 pots and sherds, the following making-sequence has been proposed:[44]

From this evidence it is clear that a clay vessel containing abundant charcoal or plant material was thrown on the wheel and then fired under reducing conditions, so that charcoal was retained and iron reduced in the clay body. Just before completion of the firing, or during the cooling phase, air was allowed to enter the kiln and a limited thickness of the outer core was oxidized. Then, for decorative purposes, the surface was heavily smoked, and/or a thin iron-containing slip layer was reduced in smoke or burnished.

A consequence of this short oxidising spell before carbonising is that Liang-chu blackwares tend to have lighter layers beneath their black outer surfaces, and these can become apparent where the black outer skin has partially worn away.

[42] Anon. (1992b), Department of Archaeology at Peking University. See especially pp. 80–1, a stemmed cup, height 19.2 centimetres, from Shantung province, late Ta-wen-khou culture (−2,800 to −2,000), and pp. 82–3, an even finer-stemmed cup, height 17.3 centimetres, from Shantung province, Lung-shan culture (−2500 to −2000). Anon. (1993), Institute of Archaeology, Chinese Academy of Social Sciences, pp. 90–1 and 98–9, illustrates Neolithic blackwares from the middle reaches of the Yangtze river. The vessels are described as deriving influence from Ta-wen-khou culture to the north.

[43] For a good summary of southern Neolithic ceramic production, see Li He (1996), pp. 24–5.

[44] Dajnowski *et al.* (1992), p. 618. Anon. (1993), Institute of Archaeology, Chinese Academy of Social Sciences, cites a cemetery at Huang-mei 黃梅, Hupei province (pp. 98–9) and another from the Chhü-chia-ling culture 屈家岭文化 site in Ching-shan 京山, Hupei province (pp. 90–1). The vessels from Huang-mei are described as 'representing the influence of the Dawenkou [Ta-wen-khou] culture from areas north of Huaihe river.' *Ibid.*, p. 98.

CROSS-DRAUGHT KILNS

BRONZE AGE KILNS

Early Bronze Age kilns from north China show few advances on later Neolithic examples, other than the emergence of some square-sectioned rather than round-sectioned firing chambers.[45] As with Neolithic examples, early northern Bronze Age kilns are often found grouped on the edges of settlements (see pp. 8, 106–7). The greatest advances in northern kiln design occurred in about the –9th century when the true cross-draught kiln appeared. The most important example of this style is a kiln found at Lo-yang 洛陽 in Honan province, built above ground with rammed-earth walls.[46] This has a relatively small firing-chamber (about 1.3 metres square) but has the radical arrangement of firebox, chamber and exit flue on the same horizontal plane, with the square exit flue at floor-level in the centre of the kiln's back wall. This arrangement would have been an improvement on the standard up-draught design. The slower flame-speed, induced by the flame's forced horizontal travel, would have allowed more energy to be transferred to the ware, thus economising on fuel.

This cross-draught design became especially popular in north China towards the end of the Bronze Age, particularly from the Warring States period onwards. This seems to have coincided with a rise in demand for architectural ceramics such as pipes, tiles and large hollow bricks for tomb-building, with some of these last being at least a metre in length (see pp. 407–23).[47] Conventional bricks (of $2 \times 1 \times 0.25$ proportions) also became important in the Han dynasty. These heavy clay goods were too thick, too large and too heavy to be fired in the traditional up-draught kilns used for pottery vessels. Loess is a fusible material with poor strength under load at full kiln temperatures, so the widespread use of this material in kiln construction in north China must have limited kiln-floor diameters. It would therefore have been both risky and expensive to fire large bricks and tiles in ordinary up-draught pottery kilns, unless the kiln floors were completely redesigned.

It is interesting that many early cultures solved this problem by burning bricks and tiles in clamps, an extension of the open or bonfire process. Clamp-firing sets fuel and bricks together on solid ground, often in massive rectangular structures, with the outsides of the stacks usually plastered with clay. Once the fire is started, the clamps burn slowly for days. When cool, they are entirely dismantled. Sometimes (although not always) combustible material is mixed with the clay before making, and this helps to fire the bricks or tiles. Clamp-fired bricks are usually well burned, and only those in the outer skin tend to be underdone. These soft-fired bricks are often reused for the outsides of the clamps for the next firing.

[45] Hsü Yüan-Pang *et al.* (1982), pp. 9, 14.
[46] Liu Kedong (1982).
[47] Wang Zhongshu (1982), p. 148.

The Chinese approach to firing architectural ceramics seems largely to have avoided clamps in favour of permanent kilns, with the bricks or tiles set on solid level floors. A substantial firebox was placed at one end of the kiln-chamber, at a lower level than the kiln floor, while the exit flues were placed at the opposite end of the kiln-chamber, causing the flame-path to be largely horizontal. In effect, this turned the traditional up-draught kiln on its side. These kilns were sometimes dug into loess banks, and their similarity to northern loess-dug cave-houses was perhaps more than coincidence. It is possible too that the potential for cross-draught operation was absorbed, consciously or unconsciously, from traditional *khang* 炕 horizontal heating flues, with which most northern cave-houses were equipped. A further possibility is that the design was introduced to north China from the south, where both short and long cross-draught designs had been evolved at middle to late Shang dynasty sites.[48]

This tendency to build permanent kilns for brick- and tile-making in China may have owed something to the rather specific reducing atmospheres that had been developed for producing grey wares. These thoroughly reducing firings needed more control than clamp firings could provide. In fact, clamp-kilns are rare in China even today despite the huge volumes of bricks and tiles produced in the country.

Perhaps the best image of late Bronze Age kiln development in north China has come from excavations at the old city of Wu-chi 無極 in Hopei province in +1956. More than twenty kilns from the Warring States, Western Han and Eastern Han periods were excavated here, with the Han kilns showing larger chambers, longer fire tunnels, and more efficient chimneys than Warring States examples.[49]

Three Han dynasty kilns from this site are illustrated in the +1959 report, in rather grainy but clear black-and-white photographs (Fig. 66).[50] All are true cross-draught designs: one kiln-chamber is a near cube, another pear-shaped and the third somewhere between the two. The kiln with the cubic chamber is brick-built while the more organic shapes appear to have been excavated direct from the loess.

Although the geometry of brick-built kilns makes them appear more 'professional' than 'cave' kilns in construction, fire behaves much like water in its response to hard angles, and the smoother curves that are possible with excavated kilns can give superior results in firing. Indeed the latest and most sophisticated styles of Chinese brick-built kilns (such as the southern 'egg-shaped' and 'step kilns' using for firing porcelain) managed to achieve near-organic forms with brick-built structures.

The floors of the Han dynasty brick kiln-chambers are flat, solid and horizontal. The exit flues are set at the bottom of the back walls of the kiln-chambers, which are flat and vertical. The kiln-chambers narrow towards their firebox ends, with the fireboxes set at least a half a metre lower than kiln-chamber floors. The kilns are

[48] Anon. (2001, *People's Daily*).
[49] Anon. (1959b), pp. 339–42.
[50] *Ibid.*, pl. 8.

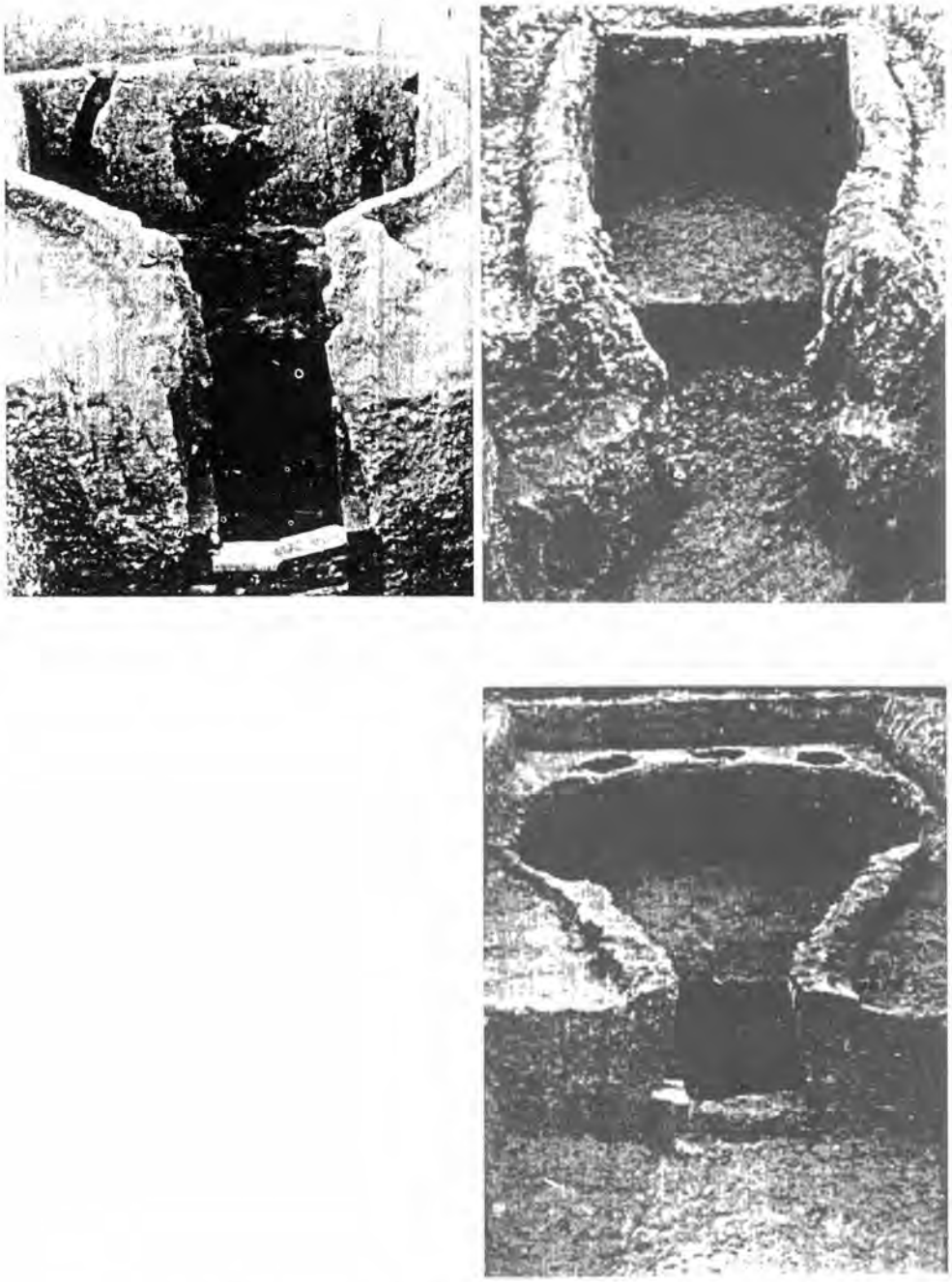


Fig. 66 Han dynasty kilns from the old city of Wu-chi in Hopei province

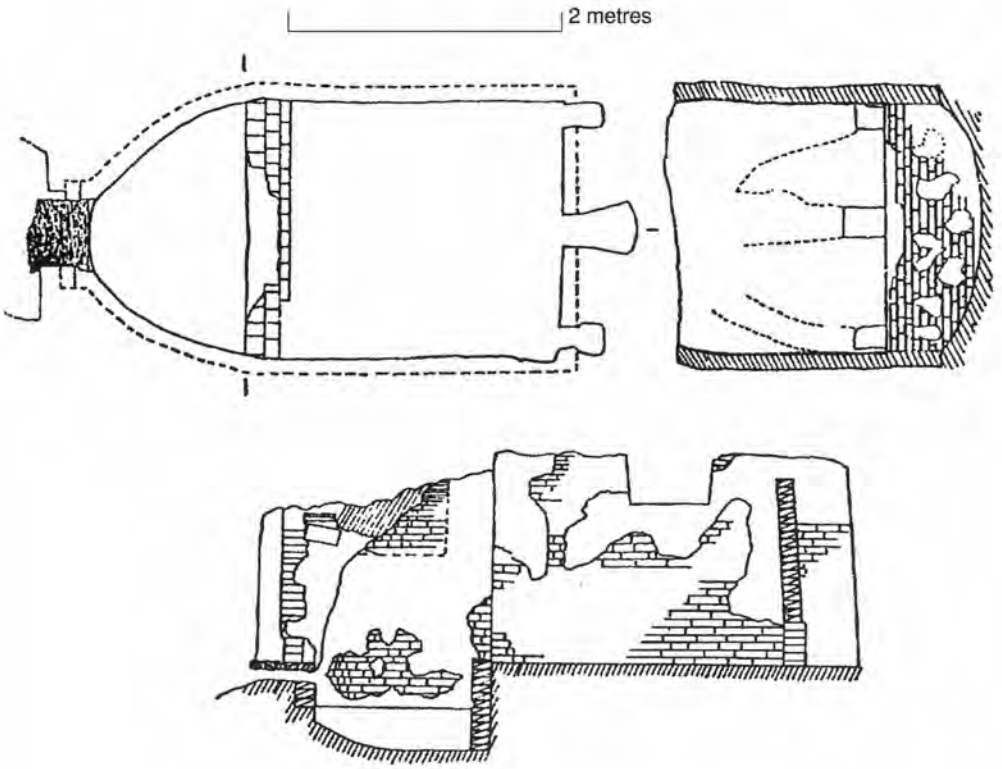


Fig. 67 Han dynasty brick kiln at Ku-hsing-chen iron-smelting site

described as 'pottery kilns', although they bear strong similarities to another group of Han dynasty kilns, this time excavated at the iron-smelting site of Ku-hsing-chen 古滎鎮, Cheng-chou, Honan province. The Ku-hsing-chen kilns were mainly used for firing 'bricks, tiles and blast-pipes'.[51] On the basis of excavated coins, the Ku-hsing-chen iron-smelting complex is dated to the –1st century.[52]

The structures of the thirteen kilns found were all cross-draught in operation, with their lower levels dug into the earth, and the kiln-chambers proper built with brick. The floors of the kilns' firing chambers were practically square, and their inside walls measured about two metres. The kiln-roofs were missing, but it seems as though the chambers were about 1.8 metres tall inside, making their setting spaces within the kilns roughly cuboid. Three small rectangular holes in the kilns' back walls led the combustion gases from the kilns. These exit flues were set at floor level: one in each corner, and one in the centre. Behind this back wall the two outer exit flues were connected to the centre flue by upward-curving channels, which

[51] Anon. (1978c), pp. 28–43.
[52] The coins were of the late Western Han dynasty, *ibid.*, p. 37.

then merged in a single vertical chimney to give a trident effect. All the kilns were burned blue-grey inside, and most of the ceramics excavated at Ku-hsing-chen (mainly vessels and tiles) were of a grey pottery material. Reduction-firing must have been practised in these kilns, but there are no indications in the reports of any structures that could be associated with hydrogen-reduction techniques. With regard to the fuel used to fire the wares, the authors make the following comments:[53]

> Judging from the accumulations of plant ash found in the fire pits, the principal fuel used was wood-chips. However, in the fire-pit of Kiln 65 were found a large number of moulded cakes of fuel. The cakes are cylindrical, diameter 18–19 centimetres, thickness 7–8 centimetres . . . The cakes are mixed with clay, and in the unburned part there is a black substance, which may be mineral coal.

The moulded cakes found in Kiln 65 were burned on a proper grate of bricks, which were set fan-like, but with channels between to direct air beneath the fuel. This is one of the first true grates described for a firebox of a Chinese kiln. Presumably in the earlier wood-burning kilns the fuel was simply burned direct on the firebox floor. This can be an entirely practical arrangement in both stoneware and earthenware firings if the fuel is placed carefully to allow good access for the air.

The use of coal for firing ceramics at the Ku-hsing-chen site is the earliest so far established for China, and use of the fuel may have spread originally from iron-smelting practice. For example, at another mid Western Han dynasty foundry in Kung-hsien 鞏縣, Honan province, three types of fuel were used. They were wood, coal and coal-cakes, the last being 'coal powder mixed with clay and quartz'.[54] In some cases it seems as if the Ku-hsing-chen kilns near Cheng-chou may have served for both ceramic and metallurgical purposes, as the authors note:[55]

> We therefore conclude that these kilns, besides being used for firing bricks, tiles and blast pipes, may also have been used for many other functions: firing moulds, annealing iron implements, firing ceramic vessels, etc.

The mention of firing moulds refers to the extraordinarily efficient techniques devised by Han dynasty iron-founders for mass-producing small castings in stacked ceramic moulds. The ceramic moulds were themselves duplicated from iron master-moulds, dusted with some releasing powder such as bran. In this casting process the fired ceramic moulds would have been taken from the cooling kilns while still at temperatures of about 300°C, and then filled with molten iron.[56]

A large cross-draught kiln for firing ceramic moulds intended for iron-casting, and dated to the Eastern Han dynasty, was excavated at Wen-hsien 溫縣 in Honan province and described in detail in +1983. The Wen-hsien foundry mainly

[53] *Ibid.*, pp. 33–4.
[54] Hua Jue-ming (1983), p. 114. 'Clay and quartz' here may mean loess, a natural clay-quartz mix.
[55] Anon. (1978c), p. 33.
[56] It is believed that the moulds were used hot because the 'runners' in the mould were so narrow. Cold moulds would have frozen the iron before it filled all the stacked spaces. See Hua Jue-ming (1983), p. 107.

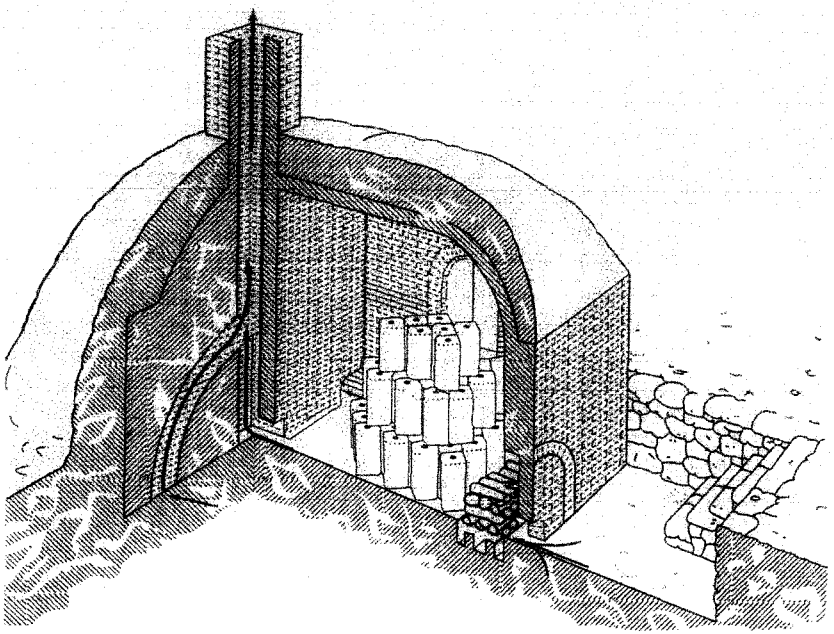


Fig. 68 Eastern Han dynasty kiln at Wen-hsien for firing and preheating moulds for iron-casing. The kiln's interior is three metres cubed

produced iron-castings for horse-drawn vehicles, manufacturing sixteen types of casting in 36 sizes. The brick-built mould-kiln at Wen-hsien was the same form as the Ku-hsing-chen kilns, but its firing chamber was larger, at nearly three metres cube, and the kiln was fired with wood.[57]

NORTHERN CERAMICS AND IRON-CASTING

In the history of technology what does not occur may be as significant as what does, and one example of this phenomenon must be the close association of ceramics with iron-casting at Western Han dynasty sites such as Ku-hsing-chen. This again raises the question of why high-temperature ceramics were so slow to become established in the north, despite ceramics and metal production often operating at the same sites. This is particularly relevant to Ku-hsing-chen as unglazed white stonewares were produced nearby at Cheng-chou in the Shang dynasty. By the Western Han

[57] Hua Juc-ming (1983), p. 114.

dynasty everything was in place at Ku-hsing-chen for some useful technology transfers to occur, from iron-smelting to ceramics.

For example, the iron furnaces at Ku-hsing-chen used a range of refractory bricks, made from materials that could have provided both bodies for stoneware and refractories for kilns. The designs of Han dynasty cross-draught brick kilns were essentially the same as those used later in the north for stonewares and porcelains in the Sui-Thang period. Thus no radical changes in kiln design would have been needed for stoneware-making, other than superior refractories for building the kilns. The temperatures used for cast-iron production at the site were suitable for firing stoneware, and even the furnace slags, produced in such large quantities, were essentially lime-eutectic glazes in their compositions.[58] Nonetheless, and despite all these useful elements being associated at some sites in the Western Han dynasty, no transfer of technology seems to have occurred. Grey- and red-fired loessic clays remained the staple ceramic types in north China until stoneware production at last became properly established in the north in the +6th century.

Later Northern Brick Kilns

The relatively small size (2–3 metres cubed) of Han dynasty northern brick kilns was probably dictated to some extent by the fall-off of heat that occurs from firebox to exit flues in cross-draught kiln designs. Kilns deeper than this might be badly underfired at the back. This fall-off happens with wood firing, but it is most obvious with coal, which has an altogether shorter flame-length. Building the kilns to the same length, but wider, does not seem to have been attempted by earlier Chinese brick-makers. This was perhaps because kiln roofs excavated from loess tended to collapse with a greater width, while wide-vaulted brick roofs would have been hard to construct. Perhaps for these reasons brick kilns tend to occur most usually as multiples in China until the Ming dynasty, rather than as single giant structures.

This 'multiple' approach can be observed as late as the Sui-Thang dynasty in a complex of roof-tile kilns excavated at Lo-yang.[59] The kilns at Lo-yang were constructed by first digging a deep ditch, four metres wide at the top and two metres wide at the bottom, and then tunnelling the kiln-chambers at right angles to the ditch walls. These excavated kilns branched from both sides of the ditch, as the authors write:[60]

> The group of kilns were laid out in two rows running north and south, with the mouths of the kilns staggered in relation to each other. Seven kilns were cleared during this excavation.

The cross-draught Thang dynasty tile kilns at Lo-yang were of traditional Han dynasty style, being roughly three-metre cubes with chambers narrowing both in height and width towards the fire-mouths. The glazed interiors of the kilns suggest

[58] See Anon. (1978c), p. 38, table 3.

[59] The main products of these kilns were grey 'flat' (that is, very slightly curved) roof tiles. A few square decorated bricks were also excavated from within the kilns, as were some round tile-ends.

[60] Anon. (1974b), p. 262.

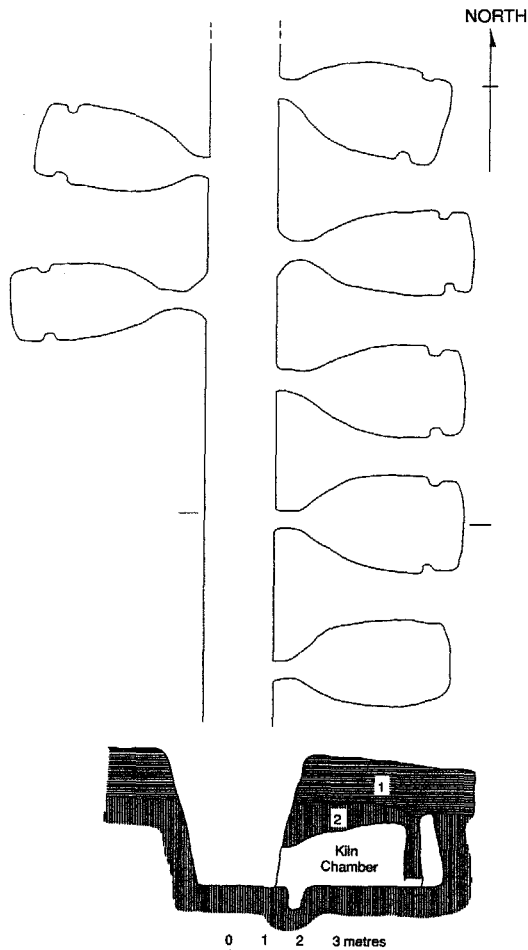


Fig. 69 Thang dynasty tile kilns from Lo-yang

wood firing and the tiles produced by these kilns seem to have been used solely for construction work within the palace. From datable evidence at the site the authors suggest that 'the kilns were in operation from AD 605 at the earliest until AD 731 at the latest.'[61] This seems to suggest some uncertainty in dating, rather than that the kilns could last for more than 100 years.

[61] *Ibid.*

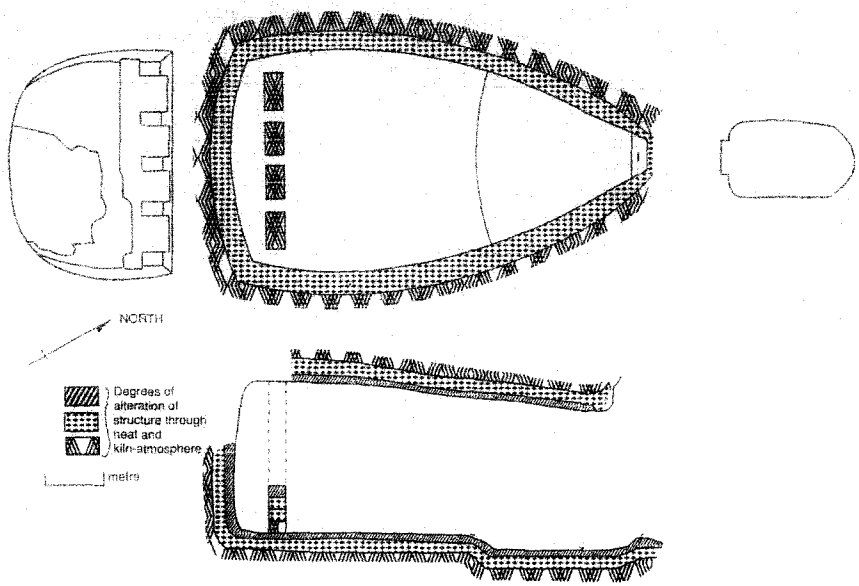


Fig. 70 Thang dynasty tile kiln from Szechuan province

Similar kilns to those used at Lo-yang also operated in Szechuan province in the Thang dynasty, where one example has been excavated three kilometres to the east of Hsi-chhang city 西昌市.[62] This too was one of a series dug into an earth bank, and the kiln examined in detail had a firing chamber about two metres cube, with five exit flues at floor level in its back wall. As with most kilns of this style, the chamber would have been set by the workers' carrying the tiles through the kiln's fire-mouth. Once the kiln was full, this doorway would have been largely bricked-up ready for the firing proper, with a space left for stoking the firebox. Some 0.6 metres of charcoal ashes were found in the space where the firemen worked in front of the firebox, so the assumption here is that the fuel used was wood. Like the Lo-yang kilns, the main products from this Szechuan kiln were flat tiles, together with some eaves-tiles and end-tiles.

While the construction of rows of small kilns, branching from a deep ditch or bank, seems to have been the main Thang dynasty solution to raising brick production, occasional examples exist where a number of small kilns have been merged into wider structures. The origins of these wide kilns can be seen in the use of three separate fireboxes in a row, and also three separate sets of trident-shaped exit flues

[62] Anon. (1977b), pp. 57–9.

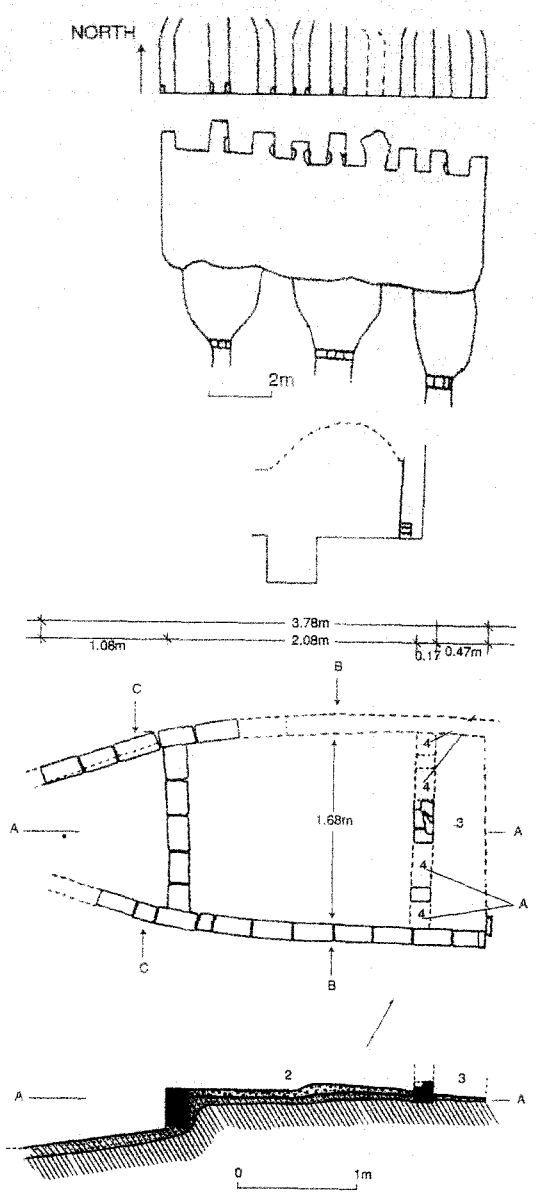


Fig. 71 Thang dynasty brick kiln

at the back of the structure.[63] Quite how this kiln was roofed was not clear from the excavation, as it was missing its upper levels, but it is believed that all three fireboxes were fired together, and that the kiln was treated as a single structure.

It appears that by the Ming dynasty in north China, a solution was found that combined the advantages of reduction-firing with the building of much larger, and therefore more economical, kiln-chambers. These were large, cross-draught kilns of horse-shoe-shaped ground plan, *c.* eight metres in diameter, but with open tops. Once the kilns had been stacked with raw bricks a temporary roof of clay was constructed directly on the top of the setting, to seal the structure. This cleverly avoided the problem of building a large-spanned roof, while still closing the kiln effectively, and allowing good control of the kiln-atmosphere. These large coal-burning kilns were fired in the usual way, with a single large firebox and two chimneys. Towards the end of the firing, the clay 'roof' was drenched with water, though once again it is hard to be sure whether fast cooling or hydrogen reduction was the prime effect. A modern example, observed and filmed by Oliver Moore in +1998, took seven days to fire to a maximum temperature of about 1,150°C.[64] Such kilns appear to have been used for reduction-firing the millions of massive loess bricks used to rebuild the Great Wall during the Ming dynasty.

The Cross-Draught Kiln Design: A Summary

The cross-draught style of kiln design, apparently first used in north China in the late Western Chou period was a simple and efficient system. As the combustion gases were forced to travel semi-horizontally their flame-speeds were slowed, and this allowed more energy to be transferred from the burning fuel. Lower flame-speeds made higher kiln-temperatures easier to reach and generally improved fuel-economy in firing. Another advantage of the cross-draught design was its solid floor. This allowed the weight of the wares to be taken straight to a solid base, rather than a perforated floor above the firebox. The heat in these kilns could therefore be increased substantially, if necessary, without causing the kiln's floor to fail, or the wares at the foot of the setting to be seriously over-fired. Placing the exit flues at the very base of the kilns' back walls also countered the tendency of the flames to linger in the higher areas of the firing chamber. The flues coaxed the flames downwards, as they travelled from the firebox towards the exit flues.

All these factors helped to improve evenness in firing. Nonetheless temperature distribution in cross-draught kilns always shows some fall-off of heat towards the bottom and back of the firing-chamber. That leaves the potters the options of either

[63] See Chao Chhing-Yün (1993), pp. 10–11, plate 5.2–5.
[64] Oliver Moore, pers. comm.

accepting and exploiting the situation,[65] or attempting to minimise the effects through various firing and setting strategies. Uneven firing in cross-draught kilns can be lessened, though not eliminated, by shortening the distance from firebox to chimney flue. Holding the kilns at full heat for prolonged periods, in an attempt to balance the internal temperature through conduction, also helps to ameliorate the effect.

[65] Differing firing temperatures within the same chamber was a feature exploited from the later Ming dynasty onwards at Ching-te-chen, in the 'egg-shaped' kilns (see pp. 366–75).

MAN-THOU KILNS 饅頭窯

HIGH-TEMPERATURE KILNS IN NORTH CHINA

When high-temperature glazed wares began to be made again in any quantity in north China, apparently in the mid +6th century, traditional northern earthenware tile kilns seem to have provided the starting point for the high-temperature kiln designs. Some of the earliest examples of northern stoneware and porcelain kilns have been excavated in the Kung-hsien district of Honan province and show interesting improvements and modifications on traditional northern tile kiln construction. The Kung-hsien workshops are regarded as among the earliest makers of glazed stoneware in north China, with C^{14} dates of kiln-site charcoal placing the wares at the Li-ko-ta-tshun 李疙瘩村 site to the Northern Chhi period.[66]

Early Kung-hsien stoneware kilns have been described as being of three types:[67]

> the natural draught *mantou* [*man-thou*] kiln, the natural draught kiln with pillars on the bottom, and the prototype hor-bottom down-draught kiln.

In the first design the wares seem to have been placed straight on to the kiln floor, which must have led to some serious underfiring at the foot of the setting. This seems to have been corrected to some degree in the second design where the wares were raised from the kiln floor on stout fireclay pillars, made lower at the front, nearer the firebox, and higher towards the exit flues in the kiln's back wall. The third design attempted to make the firing more even still by placing the firebox deeper within the kiln-chamber, with some of the wares being set either side of the combustion area. Although this is described as a 'prototype down-draught kiln' in the report, it is still essentially a cross-draught design as the gases leave the kiln-chamber at the opposite end to the firebox, and the flame-path is largely horizontal.[68]

When high-temperature kilns at Kung-hsien are compared with near-contemporary tile kilns at Lo-yang, a number of differences emerge. The fireboxes were larger in the high-temperature kilns, and were also set at lower levels than the kiln settings. True grates with fire bars were also present, which was a further sign that the fireboxes needed to perform to superior levels of efficiency. All these early kilns at Kung-hsien were fired with wood.

[66] Yang Wenxian & Zhang Xiangsheng (1986), p. 302.

[67] *Ibid.*, pp. 302–3. The name *man-thou* 饅頭 refers to the kilns' domes, which resemble the steam-baked bread rolls, *man-thou*, popular in north China. The term 'horse-shoe-shaped' is also used for northern cross-draught kilns. In this case the description refers to the ground plan.

[68] In true down-draught designs the flames rise up from the fireboxes to the crown of the kiln, but are then drawn vertically downwards through the wares against gravity by the 'pull' of the chimney, and into a central flue. In true down-draught kilns therefore the main movement of flame is directly downwards. This is a European rather than a Chinese kiln design, but one that was not developed until the +19th century. See Kingery & Vandiver (1985), p. 175; Green (1999), pp. 58–9.

Perhaps the most comprehensive image for early stoneware and earthenware production in north China has been revealed at the Yao-chou 耀州 kiln site at Huang-pao 黃堡, particularly from an archaeological dig that lasted from Autumn +1984 to Spring +1990. The Huang-pao excavations uncovered seventeen workshops of the Thang, Five Dynasties, Sung and Chin dynasties. They comprised three Thang dynasty *san-tshai* 三彩 kilns, twelve high-temperature kilns, one lime kiln, eighteen ash pits, one cave warehouse and materials store, and hundreds of ceramic vessels, kiln furniture and potters' tools. These are described in two reports both published in +1992, and are referred to elsewhere in this volume on pp. 428–34.[69]

The Huang-pao site is particularly valuable as it not only allows comparisons to be made between *san-tshai* and stoneware kilns of the Thang dynasty, but also embraces some seven centuries of kiln development in northern China. The Yao-chou kilns also illustrate important changes that occurred from wood firing to coal firing in north China in the Northern Sung dynasty. However, this very continuity of production at Huang-pao has raised some problems in interpretation, as the archaeologists explain:[70]

> The earlier the time the more serious the damage. Even workshops and kilns of the same period in different areas present an overlapping situation, which makes it difficult to recognise the characteristics of each period.

Nonetheless ground plans for seven kilns from the Thang to Yuan dynasties were surveyed, with all the kilns found within a ten mile area of the Yao-chou kiln-complex.

Both Thang dynasty *san-tshai* and stoneware kilns at Yao-chou were of cross-draught style and were built from brick, coated with coarse sand. They were fired with wood and the similarities between their designs and those of typical Han dynasty tile kilns are striking. The main differences between the low- and high-temperature Thang dynasty kilns lay in firing-chamber proportions and overall sizes. In detail, the *san-tshai* kiln was longer than it was wide, while the stoneware kiln (although larger) had a width that exceeded its length. The floor area of the *san-tshai* firing chamber was 2.08 metres long, by 1.68 metres wide (3.5 square metres), while the stoneware kiln had a floor space about 2.86 metres long, by 3.4 metres wide (9.7 square metres).

Judging from published drawings, the brick walls for these kilns were single course and rather thin, being only about 16 centimetres thick in both cases. This refractory lining must have been backed by substantial thicknesses of earth and/or stone, both for buttressing the structures to take the domes' thrust and also for insulating the kiln-chambers. No doubt this material had been robbed for building new kilns when the old kilns were abandoned.

[69] Anon. (1992a), vol. 1, pp. 15–25; Tu Pao-Jen (1987), pp. 32–7.
[70] Anon. (1992a), vol. 1, p. 16.

How the potters reached the kilns' interiors is not obvious from the surveys, as both kilns were missing the northern walls to their ware-chambers, where any side doors might have been sited. It seems possible that both kilns were set from their firebox ends. This was apparently the usual method for earlier northern tile kilns, and is still general practice for *man-thou* kilns in both north and south China.

Perhaps the most important aspect of the series of kilns at Yao-chou is the well-preserved transition from wood firing to coal, evident at the site. This is a development that must have been paralleled at many northern stoneware and porcelain sites in the Northern Sung dynasty.[71] As mentioned on p. 500, coal was found at Yao-chou in a stove in a Thang dynasty *san-tshai* pottery workshop that had been flooded and hastily abandoned by the potters. This suggests that coal may have been known and used for domestic cooking at Yao-chou in the Thang dynasty, and that this domestic function influenced its choice as a fuel for kilns. The source of the coal was the middle of the 'black belt' along the Wei river in Shensi province.[72]

ADVANTAGES OF COAL

Weight for weight, coal has a higher calorific value than wood (typically 12,000 Btu/lb. for coal against 8–9,000 Btu/lb for wood: 4,440–4,995 kilocalories per kilogram). Its general cubic form also makes it a more compact fuel (50.5 lb./cu ft: 817.8 kg/cu. metre for loose coal against about 25 lb./cu. ft: 404.85 kg/cu. metre for split wood).[73] Thus one cubic foot of loose coal might have a calorific value of 600,000 Btu (150,000 kg-calories) while a cubic foot of split wood might have a calorific value of 300,000 Btu (75,000 kg-calories).[74] This means either that about half the grate area was needed with coal than with wood, or that the kiln needed stoking half as often. It was also easier to reach high kiln temperatures when burning coal. Coal in north China is also enormously abundant, and therefore cheap, and it tends to occur in the same geological formations as provide clays for stoneware and porcelain-making. This meant that many kiln sites, originally established with wood-burning kilns, were able to exploit sources of coal local to the workshops once word had spread of how to burn coal in pottery kilns. Clays found beneath coal seams often

[71] Wood to coal transitions in kiln-firing have been described for: the Kuan-thai kilns, in Anon. (1997d), p. 578; the Ting kilns, in Chang Chin, Liu Mu-Chen & Liu Kho-Tung (1983), p. 27; and some Szechuan kilns, in Chen Liqiong (1989), pp. 476–8. Coal as a fuel was first mentioned in literature during the Han-Three Kingdoms period, see Anon. (1997a), pp. 50–1. The latter report quotes *Thai Phing Yü Lan* that mentions the hoarding by Duke Tshao 曹公 (*d.* +220) of anthracite or coke for its excellent firing properties and *Shui Ching Chu*, ch. 10, that notes the storage of coke as a valuable commodity by Wei dynasty emperor Thai-Wu 魏太武帝 (+424–452) at his fiefdom in present-day Hopei province.

[72] Hsüeh Tung-Hsing (1992), p. 25.

[73] Data from Marks (1924), p. 633 and p. 646. Loose coal weights are an 'average of 3 samples from north China'; wood weights vary from 2,300 lbs (1,043 kilograms) a cord (willow) to 4,600 lbs (2,086.5 kilograms) a cord for Hickory, both in a dry state. A cord of wood is a stack 8 feet × 4 feet × 4 feet, that is 128 cubic feet (3.62 cubic metres).

[74] *Ibid.*, pp. 633–47.



Fig. 72 Sung dynasty Ting kiln site at Chien-tzhu-tshun 澗磁村 with coal in the foreground, +1997

show good refractoriness, which makes them suitable for sagger-making, and also for the construction of kiln bricks.

The disadvantages of coal as a fuel are its short flame length (due to its lower content of volatile material) and the large amounts of heavy cinder and clinker that it tends to generate in firing (typically 6–7% of the coal's weight compared with 0.2 to 0.6% for wood). Coal ash comes partly from the altered woody material that made the coal, but also from clay-like silts in the original peaty sediments, and mineral material from the coal's associated rocks.[75] Its short flame length sets rather strict limits on the lengths of cross-draught kilns, while the gritty nature of its ash meant that the glazes on open-fired wares could be spoiled by coal-ash disturbed by stoking. Reducing atmospheres also tend to be more difficult to manage and sustain with coal than with wood. The substitution of coal for wood was not therefore an unalloyed advantage at Yao-chou, although its abundance was probably decisive in its introduction. Even so, the change to coal for firing stoneware and porcelain at the site involved some major alterations in kiln structures, particularly in the firebox area of the kiln where the fuel was burned.

[75] *Ibid.*, pp. 535–8, table 2, and p. 647, table 8.

Burning Wood and Coal in High-Temperature Kilns

Many northern kilns were situated near to or actually on top of coal mines. References to the link are made in the local gazetteers for Ting-chou and Yao-chou.[76] In the Southern Sung dynasty Hung Mai 洪邁 noted that coal supplies at Pai-thu-chen 白兔鎮, Hsiao-hsien 蕭縣, Chiangsu province, attracted potters to make white porcelain there. There were over 30 kilns in the area, employing several hundred workers.[77]

Wood produces very little ash when thoroughly burned; ash is also rather light and easily drawn through the kiln by the fire's draught. For both reasons little wood ash tends to accumulate in the kiln's fireboxes. Nonetheless wood-burning kilns still need substantial firebox-volumes to accommodate the bulky wood fuel, and also to provide space for the embers (charcoal) to develop and burn to ash. The burning of char can provide as much as half the energy gained from burning the wood, so its combustion, both above and beneath the firebars, must be well organised and properly ventilated.[78] However, once these charcoal embers have built to a certain level, they tend not to increase much in volume during firing, and they burn away to next-to-nothing when the firing finishes.

Coal is quite different in this regard as it produces substantial amounts of heavy ash and, sometimes, clinker, and this ash grows steadily in volume as the firing continues. The options with a coal-burning kiln are therefore either to remove surplus ash during the firing process, or to create deep ash pits below the fire bars so large amounts of cinder can be accommodated. Even with this latter solution it is often useful to design some means for removing coal ash if, for some reason (for example, a prolonged firing or particularly ash-rich coal), cinder fills the pit and begins to choke the fires.

Another useful feature for coal-burning fireboxes can be the facility to allow air into the ash pit itself. This burns the embers thoroughly, and also pre-heats some of the air burning the fuel, with consequent gains in firing efficiency. Too much air entering the ash pit can slow the firing, so some control of this air supply is vital. Structures designed to effect this control occur on a number of excavated kilns in north China.

A further problem with coal is that it needs to be supported by fire bars while it is burning, while wood can often be burned direct on the firebox floor, although the floor was sometimes stepped to admit more air beneath the fuel (see Fig. 77). Fire bars for coal-burning kilns need to be very refractory, as the burning temperatures for coal are high. Cast-iron (a familiar material in China by this time) might seem an option. The temperatures at which coal burns within the kiln's chamber, however,

[76] (*Chhung Hsiu*) *Chhü-yang Hsien Chih* (1904 edn), ch. 6, p. 13, ch. 10b, p. 1. *Tao-chou Chih* (1557 edn), ch. 4, p. 7.
[77] *I-chien Chih*, ch. 27, p. 5.
[78] McMeekin (1984), p. 42.

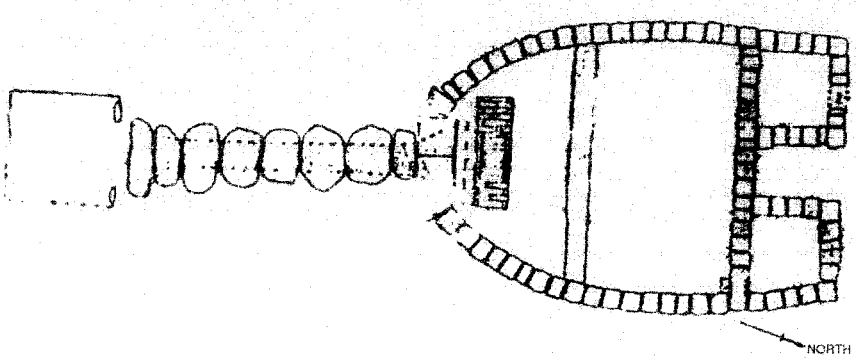


Fig. 73 Northern Sung dynasty Huang-pao coal-fired kiln with cinder-removing tunnel

were probably too great for cast-iron's fairly low melting-point of 1,090° to 1,260°C. At some northern kiln sites where coal was the prime fuel, such as Kuan-thai 觀台 in Hopei province, fire bars were made from solid clay cylinders some 8–10 centimetres in diameter.[79] At Yao-chou the grate bars in the excavated coal-burning kilns were made variously from refractory clay and from stone. The rock type is not identified in the reports but the sandstone used for the beds of the circular grinding troughs, also found at Yao-chou, might be one candidate, or refractory shale another.[80]

The most obvious difference between the floor plans of wood- and coal-fired kilns at Yao-chou is seen in the firebox area. In the wood-burning kilns the fireboxes spanned the kilns' entire widths, while in the coal-burning examples the fireboxes occupy only the central third of this area. This liberated space in the grate area could be used for setting extra columns of saggers.

All the kilns at Yao-chou had fire-holes left in the kilns' main doors, after the latter had been bricked up when the kilns were set with wares. Coal was thrown through these stoke-holes on to the fan-shaped grates inside the kiln. There were

[79] Custom-made fireclay firebars of this style are seen in a highly developed form in the large +14th-century *man-thou* kiln at Kuan-thai, designed for firing Tzhu-chou wares (the kiln coded Y8). 84 thick firebars, 0.4–0.8 metres in length and 0.1 metres in diameter, were found in the nearly complete grate, supported by columns of old saggers. The coal-burning firebox was 5.6 metres wide 2.73 metres long and 2.15 metres deep from the tops of the bars. See Anon. (1997d), p. 579, and also colour plate 111.

[80] Given the existence of the 573°C alpha-beta volume inversion with quartz, and the formation of cristobolite and tridymite from silica at high temperatures, sandstone might seem too unstable a material for kiln use, despite its good refractoriness. However Chen Tai & Hu Sheng-en (1946), pp. 193–7, found that some clay-containing sandstones from Chhung-chhing 重慶 in Szechwan province were unusually stable when used as refractories: 'No inversion of the quartz grains in the rock into tridymite or cristobolite could be detected. The interstitial clay substances fused first, and the quartz grains then dissolved into the glassy matrix on firing at high temperature . . . Being free from mineralogical and structural changes, unusually low in thermal expansion and porosity, and good in spalling resistance after firing at high temperatures, sand stones are shown to be an excellent refractory if properly employed'. *Ibid.*, p. 193.

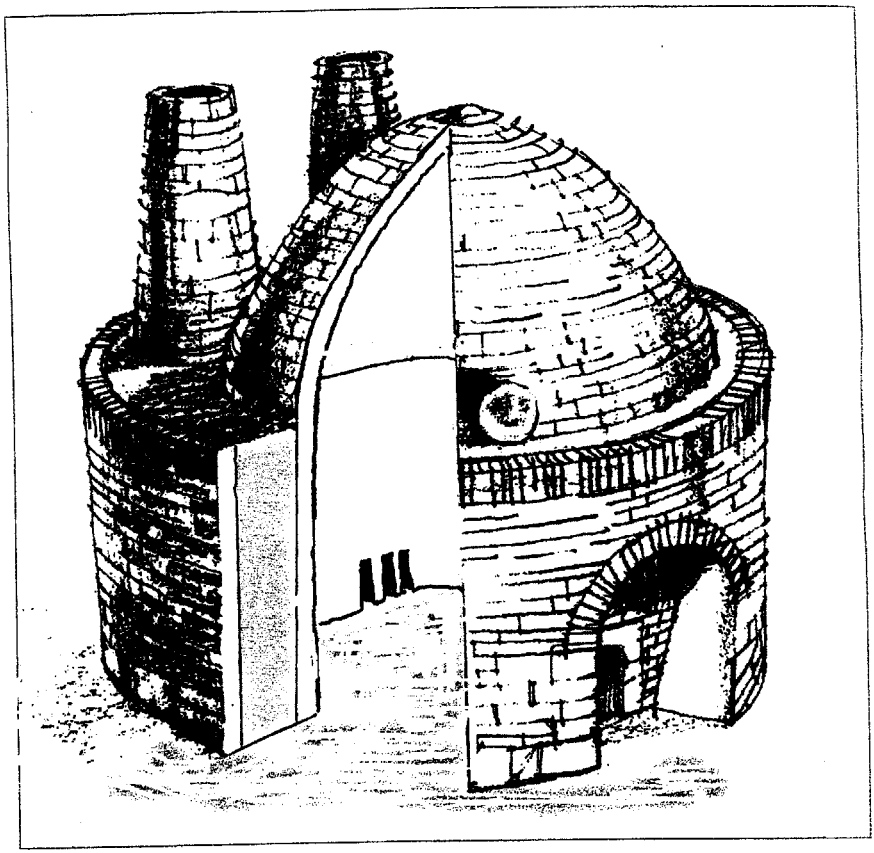


Fig. 74 Sketch of a typical Sung dynasty *man-thou* kiln from north China, with a 'slice' removed to show its structure. The thickness of the lower walls is partly for insulation, but mainly to take the thrust from the dome

also holes at a lower level for admitting air to burn the fuel, in this case beneath the fire bars. All the Yao-chou coal-firing kilns had deep vertical ash pits (up to two metres in depth) and some had tunnels leading from the ash pits to the outside air for raking back and removing surplus cinders.

In some Sung to Yuan dynasty Yao-chou kilns these ash-removing tunnels were almost three metres long, and fitted with sliding doors at their open ends to control the draught. Long-handled iron rakes have been found at the Huang-pao site, and these were probably used for drawing back the white-hot cinders from the fire pits. In the earlier style of coal-burning kiln at Yao-chou excess cinders were removed via deep tunnels that connected with the bottom of the fire pit, a

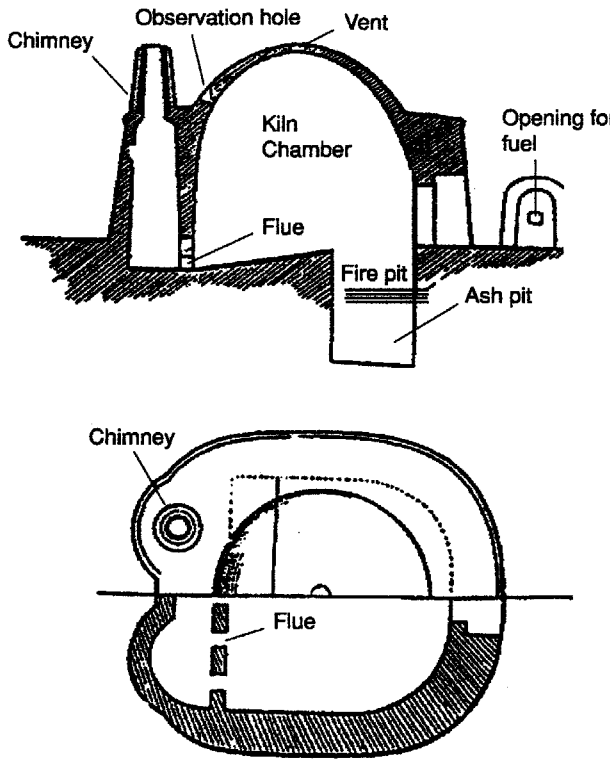


Fig. 75 Plan and elevation of a coal-burning Sung dynasty *man-thou* kiln

feature also seen on some modern *man-thou* kilns in Shansi province.[81] Later Yao-chou kilns featured cinder-removal tunnels nearer the tops of the ash pits, as shown in Figure 73.[82]

At other early sites experimenting with coal burning in China, deep ash pits developed later. For example, at Northern Sung dynasty sites such as Pheng-hsien 彭縣 in Szechuan province, and at Kuan-thai in Hopei province, the coal-burning fireboxes were as wide and shallow as those used for wood-burning kilns, and the coal burned on an improvised bed of inverted saggers and kiln props. These grates were probably completely cleared out and reset for each firing, with their widths compensating for their lack of depth. Even so, these seem to have been transitional

[81] Shui Jisheng (1989), p. 472, fig. 2.
[82] Hsüeh Tung-Hsing (1992), pp. 22–5.



Fig. 76 Two-chimney *man-thou* kiln in Honan province, +1985

arrangements and deep ember pits for coal burning and custom-made firebars were later developments at both kiln sites.[83]

CHIMNEYS ON NORTHERN HIGH-TEMPERATURE KILNS

One of the most typical, and unusual, aspects of north Chinese high-temperature kiln design is the presence of two chimneys, built side-by-side at the back of the kilns. These chimneys often combine substantial internal diameters with relatively low heights, some barely clearing the tops of the kilns' domes. Their tops, however,

[83] For a Northern Sung dynasty *man-thou* kiln plan, see Chen Liqiong (1989), p. 278, fig. 1. The *man-thou* kiln Y3 at Kuan-thai is described as dating to the period +1101–1148: 'This kind of furnace grate is an early form, and not yet fully mature for it is just composed of waste [i.e. recycled saggers and kiln pillars]. At the end of every firing it is necessary to remove for cleaning out ash, and also there is as yet no sign of the bars that are specially used in furnace grates.' Anon. (1997d), p. 577.

tend to be only about a quarter of the lower diameters, making *man-thou* kiln chimneys somewhat bottle-shaped. The width (and relatively low height) of northern kiln chimneys are the most obvious structural changes that occurred when northern kiln builders adapted traditional northern brick kilns for the firing of high-temperature ceramics.

In practice two chimneys set side-by-side avoid the building problems associated with connecting all the separate exit flues to a main single flue, and then leading this flue into a single central chimney. For example, a kiln with a row of six vertical exit flues at floor level in the back wall of the firing chamber can have three flues leading directly into one chimney, and the remaining three into the other (see Fig. 74). Two chimneys also permit better control of the right- and left-hand sides of the setting. They allow the possibility for constricting the draught in one chimney, thereby directing the main heat to the other chimney and to the other side of the setting. In a similar way, two chimneys can be used to balance reducing atmospheres within a kiln's chamber.[84]

Kiln chimneys serve two prime functions: to carry smoke from the kiln area, and to sustain and control the kiln's draft. Hot gases will tend to rise from a kiln's exit flues because they are less dense, due to increased agitation of their gas molecules with the rising input of energy.[85] These lighter gases will float upwards through the surrounding colder air. By directing the hot gases into a chimney, a continuous suction action can be generated within the kiln, and air can be drawn into the chamber. By sealing most of the kiln's structure, outside air is pulled selectively through the kiln's firebox (or fireboxes), where the strong supply of oxygen causes the fuel to burn fiercely. As the temperature of the kiln gases rises (making the gases less dense) so does this 'pull' increase. This further improves combustion by supplying oxygen to the fuel at a faster rate.[86] Consequently more fuel can be added more often, raising the temperature of the kiln and giving still more pull from the exiting gases. There is a limiting factor to this effect, however, namely that as the temperature of the chimney gases rises, so does their expansion within the chimney. Eventually a point is reached where the sheer volume of hot gas begins to slow its passage through the chimney, and the chimney's efficiency begins to fall away.

[84] The easiest way to 'damp' the draught in a kiln chimney is to let cold air into the chimney near its base through a removable brick in the chimney wall. The column of cold air drawn into the chimney restricts its draught as effectively as a horizontal 'damper', but without the risks of jamming or breaking common with sliding stone or fireclay tiles. Northern kiln chimneys often contain such damping holes. Cf. a Northern Sung dynasty kiln of the second type in Tu Pao-Jen (1987), p. 37. This feature was also observed by one of the authors (NW) on traditional *man-thou* kilns at Pheng-chheng 彭城, Hopei province, in +1995.

[85] Jacques Charles (+1746–1823) found in +1787, partly from his work on man-lifting hot-air balloons, that the volume of gas at constant pressure increases linearly with the temperature of the gas. This is now expressed as V = bT, where V equals volume, b is a proportionality constant and T equals temperature in degrees Kelvin. Thus one cubic metre of air at 20°C (293K) may occupy 4.35 cu m at 1,000°C (1,273K). For examples, see Zumdahl (1995), pp. 143–4.

[86] 'Natural draft can create large rates of air flow under the right conditions and the resulting combustion can create high temperatures, all without exterior effort or machinery, so it has been, and still is, widely used.' Rehder (1987), p. 48.

In greater detail, a kiln's chimney works very efficiently at temperatures as low as 150°C, but efficiency declines slightly as the temperatures of the gases within the chimney exceeds 250°C. This loss is not too serious until gas temperatures within the chimney approach 500°C.[87] At this point and above, chimney efficiency drops rapidly, which can be frustrating for the kiln firemen as this loss of 'pull' tends to occur when a great deal of heat is being lost to the kiln's structure, and the kiln is approaching its finishing temperature.

Perhaps the best solution to the problem, in terms of kiln design, is to increase the width of the stack, as this reduces the chimney's tendency to overheat and also allows more air to be drawn through the fuel, thereby further improving combustion. Thus the wide chimneys on *man-thou* kilns helped to keep the chimney temperatures low, while not raising flame-speed to the point where the effects from uneven firing were exacerbated.

If the 'pull' of a chimney is compared with the 'lift' of a hot-air balloon it can be seen that it is the volume of gas within a chimney that is important, rather than just its overall height. The pull of a kiln chimney is also affected by the diameter of the chimney top, as this controls the maximum speed that the kiln gases can leave the kiln. Because of their narrowed tops, northern *man-thou* chimneys, once filled with hot gases, act as 'reservoirs of pull'. This has the effect of drawing hot gases evenly from the wide kiln-chambers, through the rows of vertical slots set at the feet of the kilns' back walls. This foiled the tendency of flames to follow easy paths through the kiln, with consequent risks of overfiring in the regions where the fire has preferred to flow. Exploitation of this principle may explain the odd fact that some later *man-thou* chimneys extended up to half a metre beneath the kiln's floor, thereby increasing the chimneys' capacities without raising their apparent height.[88]

EARLY FIRING STAGES IN A *MAN-THOU* KILN

Despite the relatively low temperatures at which kiln chimneys begin to work well, it can still take some time to reach this temperature. During this period the chimney's pull is very inefficient. In the West, separate fires are often set in kiln chimney bases before firing to overcome this initial inertia. This warms their structures and encourages them to pull, a technique that is particularly useful and necessary when chimneys are built some distance from the kilns. Another, or additional, strategy, often used with Western down-draft kiln designs, is to fire the kilns in up-draught mode in the early stages of the firing cycle by simply allowing the hot gases to escape through holes in the kilns' domes.[89] Once the hotter parts of the kiln's setting are showing good colour, these ports can be covered, and the kiln's action changed to true down-draught mode. In this latter firing stage the draught from the chimney

[87] Bourry (1911), p. 217.

[88] A feature observed by NW with traditional *man-thou* kilns at the Pheng-chheng kiln site in Hopei province in +1995.

[89] Observed by NW at the S. & E. Collier Ltd brickyard in Tilehurst, Reading, UK, in +1964.

pulls the kiln gases downwards against gravity through the kiln and into the exit flues placed in the kiln's floor. Thence they pass by underground tunnels into the chimney that may be sited many yards from the kiln itself.

This practice of starting kilns in up-draught mode seems also to be common in China today, where it is used in many *man-thou* cross-draught kilns of traditional design. Holes in the kiln's dome (often four in a ring, with one hole in the centre) are uncovered at the start of the firings and the kiln gases allowed to exit upwards into the air. Once the saggers nearest the fireboxes are red hot the holes can be 'capped', forcing the gases to leave the kiln-chamber via the chimney flues, with the consequent transfer to cross-draught operation.[90] During this early up-draught stage the kiln chimneys become warm through direct conduction through the common back wall within the kiln, and therefore pull well once the transfer to cross-draught action takes place. Besides its value in heating the kilns' chimneys, this process also assists the rather slow start that all kilns need if the wares are not to explode in the early stages of firing due to the sudden conversion of pore-water to steam.

As the superstructures of *man-thou* kilns are invariably missing in archaeological excavations of Sui to Ming dynasty sites, this 'up-draught to cross-draught' practice cannot be demonstrated historically for northern kilns.[91] Its use should be suspected, however, particularly as loessic pyrometric cones have been found at some Northern Sung dynasty sites. They are similar to cones in use today to indicate when transfer from up-draught to cross-draught modes should occur.[92]

CROSS-DRAUGHT VERSUS DOWN-DRAUGHT

Mention of Western down-draught kilns raises a fundamental fact of Chinese kiln design, the cross-draught principle, that reigned supreme in China from the Warring States period to the early +20th century in both *man-thou* and dragon kilns. True single-chamber down-draught designs seem rarely (if ever) used in China, and did not appear in the West until the +19th century.[93] This attachment to the cross-draught principle locked Chinese potters into a perpetual battle with uneven kiln temperatures, the reasons for which can be seen in Fig. 77.

Thus we have the paradox that China led the world in high-temperature ceramic technology, with much of its success based on the high-temperature potentials of the *man-thou* and dragon kiln designs. However, in terms of evenness of temperature both kiln types had serious faults. Coal-fired *man-thou* kilns in particular showed a pronounced fall-off of temperature towards their exit flues. That phenomenon is

[90] Shui Jisheng (1989), pp. 471–2.

[91] A diagram of the remaining floorplan of an excavated Yao-chou kiln is illustrated by Hsüeh Tung-Hsing (1992), p. 38.

[92] Shui Jisheng (1986), p. 312. In the Sung dynasty, in addition to pyrometric cones, 'testers' or 'draw-trials' were also used to determine temperatures of wares in the kiln. These testers (literally 'fire reflectors', *huo-chao* 火照) were square with a round hole pierced in the middle, and were hooked out through observation holes in the kiln on a long pole, see Hsüeh Tung-Hsing (1992), pp. 39–40.

[93] Green (1999), pp. 58–9.

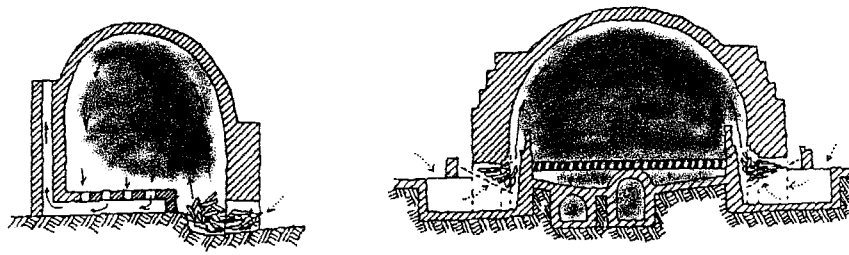


Fig. 77 Temperature distribution in typical cross-draught and down-draught kilns compared (the darker areas are hotter)

expressed in a detailed modern account of their use in Shansi province, published in +1989:[94]

[with a coal-fired *man-thou* kiln] it is very difficult to work out a proper firing schedule. If it were based on agreeable results occurring in the upper front section, then most of the ceramics located at the back lower section would be underfired. Conversely, if it was based on the agreeable results occurring in the back lower section, then overfiring or even collapsing might be brought about at the front upper section. With a strong desire to avoid both overfiring and underfiring, the ancient furnace men, in their life-long practice, found out the rule of high-temperature reaction taking place under various soaking durations. They understood that a long soaking period at lower temperature could produce the same thermal effect as a short soaking period at higher temperature. Based on their rich experience they finally worked out a unique firing schedule suitable for *mantou* [*man-thou*] kilns.

The long soak, described above as being typical for *man-thou* kilns in Shansi province, comes as something of a shock to modern potters, familiar with firings in medium-sized fuel-burning kilns lasting only 24–48 hours:[95]

The whole schedule for firing small to medium ceramics lasted approximately 100 hours. The first 24 hours was the baking stage. In the next 40 hours temperature went up steadily, after the pyrometric cones in the second row [of saggers] bent down, the top gas outlet should be closed [i.e. the transfer to down-draught operation] . . . After the pyrometric cones in the last row bent down, the kiln should be held at this temperature for ten hours. For firing big objects the whole firing schedule might last as long as 10–11 days, in which the soaking period lasted 50 hrs.

Even the ten-hour soak, quoted for smaller wares, is a very substantial period in a relatively small kiln of two to three metres in diameter, but apparently the practice still only ameliorated, rather than resolved, the unevenness problems common to coal-fired *man-thou* kilns:[96]

[94] Shui Jisheng (1989), pp. 471–2. The times quoted for firing the smaller wares only add up to 74 hours of the suggested 100. The difference may be the 'water-smoking' stage, or it may refer to the cooling.
[95] *Ibid.*, p. 473.
[96] *Ibid.*, p. 473.

In spite of the long soaking period, the temperature gradient was still remarkable. Thirty years ago a test was carried out for a mantou [*man-thou*] kiln . . . to measure the temperature gradient at the final stage of firing and it showed that the difference between the front upper section and the back lower section was no less than 100°C.

Even in modern European down-draught coal-fired kilns, there can still be problems in achieving even temperatures within the setting. The type of coal used can be crucial at this stage, as Ernst Rosenthal explains:[97]

During the last period of the firing the use of long-flame coal is essential. The long flames produced carry the heat to the middle of the oven, which would be extremely difficult to heat by radiation or convection. In the case of both down-draught and up-draught kilns, the firing-time could be much reduced if it were possible to heat the inner parts of the kiln as quickly as the outer parts. A proportion of the ware is, in fact, subjected to heat treatment much longer than is needed, owing to the necessity for bringing the inner part of the kiln to the required temperature at the final stage.

How much this modern experience with *man-thou* firing in China can be applied to coal-fired northern *man-thou* kilns of Sung to Ming dynasty date is still difficult to say, but similarities in floor plans make such parallels probable. In addition, the microstructures of Sung and Chin dynasty monochrome-glazed stonewares suggest that prolonged soakings at high temperatures may have been practised in *man-thou* fired wares. Chün wares 鈞窯, for example, can show highly mullitised bodies, strong interaction zones between glaze and clay, and the formation of 'dog-tooth' crystals of cristobolite around any surviving quartz grains in their glazes.[98] In Yao-chou wares anorthite development can be very pronounced at the body-glaze interface, despite the glazes being relatively low in calcia.[99] These phenomena are all indicative that the wares were held for lengthy periods at high temperatures within the kilns.

COOLING

One problem with the long soaking of glazes is their tendency to devitrify and to become matt through the effects of excessive micro-crystallisation. It is not impossible that rapid cooling was practised in many northern kilns to minimise these effects. This may well have involved the unbricking of the kiln door when the kiln had finished firing, allowing cool air access to the white-hot wares, which were protected by saggers. This extreme technique was certainly used with later Ching-te-chen porcelain kilns, in order to discourage mattness, and to give brighter qualities to the glazes. Taking the kiln door down once firing had finished was also common in North Staffordshire in England, with the large up-draught coal-burning kilns used to fire white earthenware and bone china

[97] Rosenthal (1949), p. 105.
[98] See, for example, Kingery & Vandiver (1986a), p. 97, writing on Chün glazes.
[99] Rastelli *et al.* (2002), p. 188.

until the mid +20th century. Cooling rates faster than might be expected from these rather massively constructed kilns can also be inferred from the microstructures of some Northern Sung and Chin dynasty Yao-chou wares, analysed recently at Oxford.[100]

LONG SOAKING

One of the side effects of soaking times as long as ten hours at high temperatures would have been a high consumption of fuel. Relatively small amounts of fuel are used in raising the kiln's temperature initially, but accelerating heat losses occur into and from the kilns' structures in the higher temperature range. Large amounts of fuel are then needed both to sustain and to raise the temperature of the kiln's setting.

Wood-fired *man-thou* kilns would have needed less soaking time because the flames from wood are longer and the temperature gradients within wood-fired kilns less extreme, with less need to even the kiln's heat through soaking and conduction. By the +10th to +11th centuries north China was becoming seriously deforested and in retrospect the general move to coal firing that began at this time can be seen as vital for northern stoneware's and porcelain's continuity and development. This change of fuel for ceramic production was also paralleled in the iron and steel industries, where charcoal began to be displaced by coke.[101]

The fortunate, and widespread, association of stoneware clays with coal deposits in northern China allowed the change from wood to coal to happen smoothly at many kiln-complexes north of the Huai river–Chhin-ling mountains 淮河秦嶺山 divide. Thus no major relocations of northern stoneware and porcelain kilns were necessary to exploit the new fuel.[102] Although coal as a fuel was first mentioned in literature during the Han to Three Kingdoms period (see p. 316), archaeology has traced its initial use at ceramic kilns as happening in the +10th to +11th centuries at Huang-pao in

[100] *Ibid.*

[101] Wagner (2002, in press) writes: 'The Chinese "commercial revolution" of the 11th century was accompanied by a number of important technical developments. In the iron industry, the last major advances in blast furnace design were made. Water power was widely used for the blast, and coal and coke began to take the place of charcoal for the fuel.' In an earlier paper (Wagner, 1985, p. 37) Wagner argued that the assumption should not always be made that coal would be cheaper than charcoal during this period in north and central China, in every situation. However, he added the proviso that: 'The economic advantage of charcoal disappears, of course, when consumption increases beyond the level of ecological equilibrium.' Menzies (1996), p. 666, suggests that forestry also declined with the widespread adoption of coal: 'In China the technology for using coal in iron smelting was available much earlier than in Europe. The early availability of coal as a substitute for charcoal meant that there was little incentive to practise forestry to fuel the growth of industry. By the late +12th C, however, the economic equation involving the demand for iron, and the relative costs of charcoal and coal, favoured the widespread adoption of coal. Improvements in agricultural technology at the time may also have altered the equation by changing the relative values of land used for agriculture and for forestry.'

[102] Industrial relocation happened in England when a wood-to-coal transition was forced by a Royal edict in the early +17th century, and glass-making transferred from the forest of southern England to areas such as the western coal fields near Bristol. The royal order was given by King James 1st on 23 May 1615 (Royal Proclamation no. 42). See Weedon (1984), pp. 15–16.

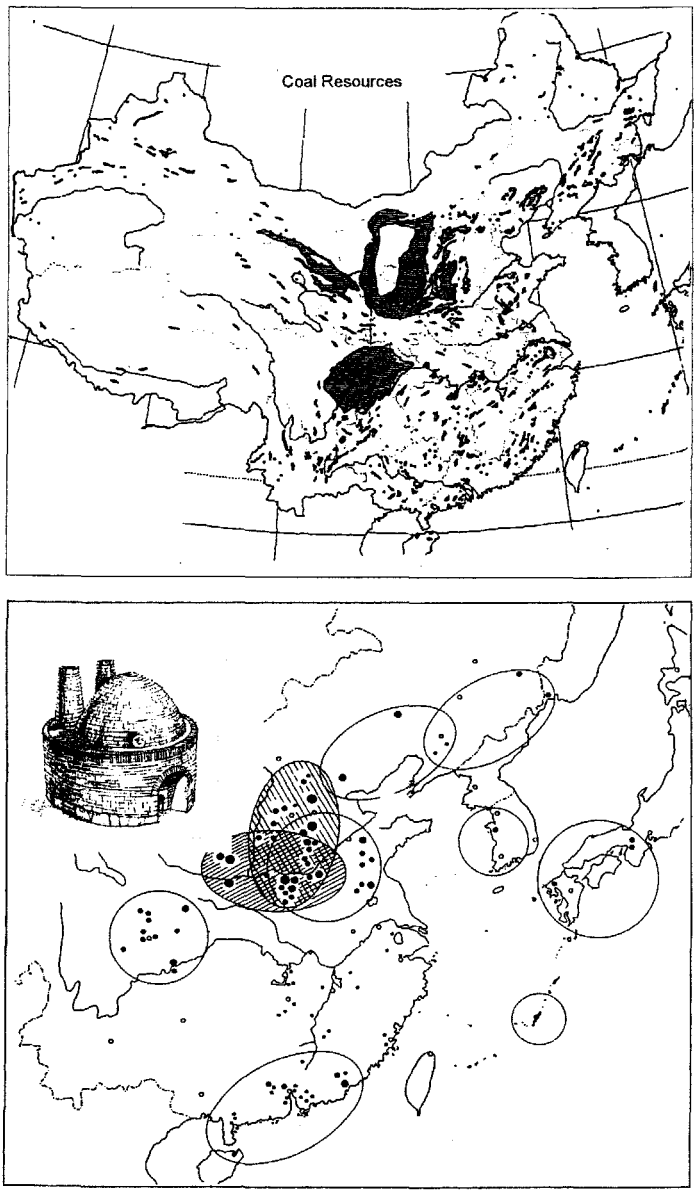


Fig. 78 Distribution of *man-thou* kilns in China compared with China's coal deposits

Shensi province, at Kung-hsien and the Chün kilns in Yü-hsien 禹縣 in Honan province, and at the Kuan-thai, Hsing and Ting kilns in Hopei province.[103] Despite the longer firings that the adoption of coal involved, the abundance of the fuel still made its use a sound prospect. This in turn contributed to the significant expansion in stoneware and porcelain production that occurred in north China in the Northern Sung dynasty.

Bearing all these factors in mind, it seems that northern stonewares and porcelains must have been expensive wares to fire, compared with equivalent wares made in the south. Northern wares were fired in relatively small kilns, with unfavourable ratios of kiln setting-space to total kiln-mass. This added to fuel costs as so much energy went into heating the kiln structures. With traditional *man-thou* kilns using coal these disadvantages were compounded by the extended soaking times necessary to avoid serious underfiring of the cooler parts of the setting.

DISTRIBUTION OF *MAN-THOU* KILNS IN CHINA

The earliest examples of high-temperature *man-thou* kilns in China tended to occur in Honan province during the Northern Dynasties, but kiln sites in Shensi, Shansi, Hopei and Shantung provinces soon adopted the designs, which became general in the north by the Thang dynasty. *Man-thou* kilns even occur in the north-west of China, in the Ninghsia Hui autonomous region 寧夏回族自治區, first in the Western Hsia dynasty (+1038–1227), and then in the Ming and Chhing periods. The Ling-wu 靈武 site was particularly productive. Coal and clay are abundant in this near-desert region, together with good transport provided by the nearby river system.[104] In terms of kiln design, the exit flues seem large in the Ling-wu kilns, perhaps because the site's elevation of 1,287 to 1,312 metres meant that flue sizes and chimney heights were enlarged to allow for the thinner, less oxygen-rich, air.[105]

A north-eastern outpost of the *man-thou* design is found at Hai-chheng 海城 in Liaoning province, as Rewi Alley and Wanda Garnsey report:[106]

> The potteries there were distinguished by their square kilns which functioned all through the T'ang [Thang], Liao and Chin periods. Measuring three metres by three metres square, these kilns were often used in north China where the potters built their furnaces on the flat ground using coal for firing . . .

The tendency for *man-thou* kilns to be used in areas with extensive coal deposits can also be seen in some areas of south China (see fig. 78 above), where a cluster of kilns

[103] See, for example, Anon. (1997d), p. 578; Chang Chin, Liu Mu-Chen & Liu Kuo-Tung (1983), p. 27; and Chen Liqiong (1989), pp. 476–8.
[104] Anon. (1995), p. 15.
[105] At a height of 4,000 feet above sea level the chimney's height should be increased by 35.6% and its width by 6.3%. See Marks (1924), p. 978, table 20, 'Stack Capacities. Correction factors for Altitude'.
[106] Garnsey & Alley (1983), p. 64.

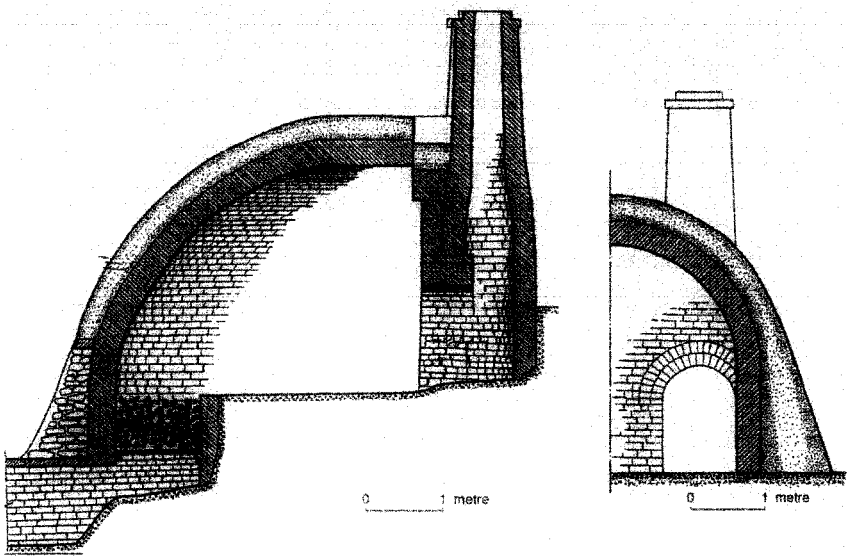


Fig. 79 Coal-burning *man-thou* kiln from the Ling-wu 靈武 site, Ninghsia Hui autonomous region

occurs in Szechuan province. *Man-thou* kilns seem to have been introduced to the area in the Thang dynasty, before which dragon kilns were the local type. A Thang dynasty model was excavated at Chheng-tu 成都, a Five Dynasties kiln at Chhiung-lai 邛崍, and a Sung dynasty oven for making imitation Ting ware at Pheng-hsien, the latter containing saggers and a sherd dated to the equivalent of +1224. Another Sung dynasty blackware kiln was found at Thu-shan 塗山. In this region Thang dynasty *man-thou* kilns were built of brick, Southern Sung *man-thou* kilns of stone. Thang and Five Dynasties furnaces used wood and bamboo as fuel. Thus during the Thang era kilns were deep, while in the Sung period a switch to coal fuel meant that the kiln became much shorter. The Sung firebox was on the level and the kiln-chamber was raised up on a step behind, with niches in the side walls to hold as many pots as possible and fully utilise kiln heat.[107] As discussed on p. 322, some earlier examples of Szechuan stoneware kilns used beds of inverted saggers to serve as grates for burning. Later examples used properly constructed stone grates, such as that used for coal-burning at a late Southern Sung kiln, excavated at Thu-shan near Chhung-chhing.

While most high-fired wares in south China are fired in the long tunnel-like wood-fired dragon kilns, the *man-thou* design was still the preferred type for bricks

[107] Chhen Li-Chhiung (1992), pp. 453–61.

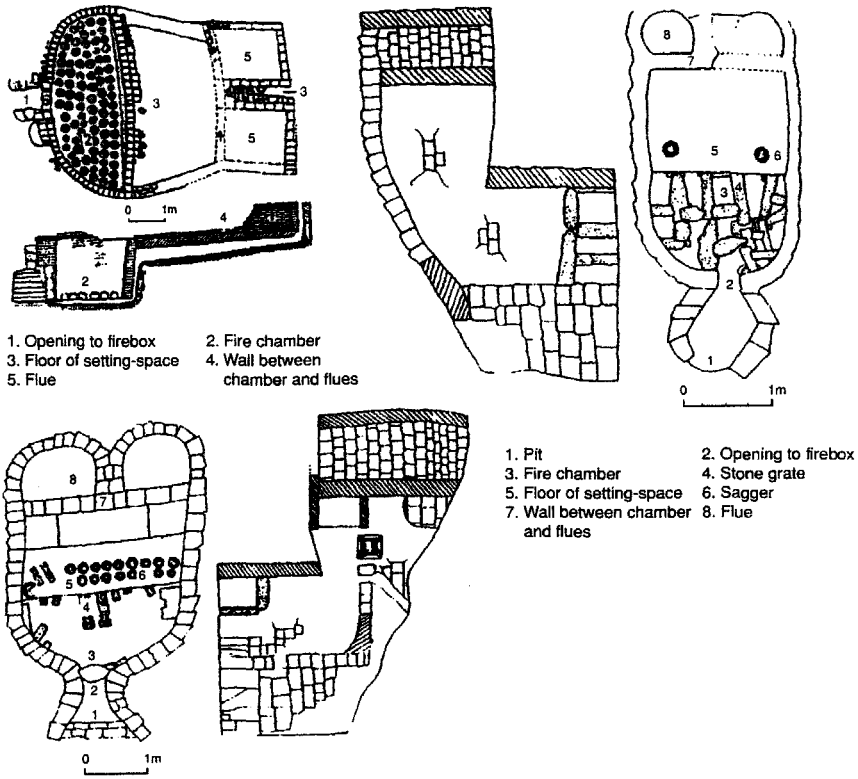


Fig. 80 Sung dynasty *man-thou* kilns in Szechuan province

and tiles, often using coal as a fuel.[108] This may be because dragon kilns are unsuitable for intense reduction-firing and reduction cooling, such as that employed by relatively low-firing kilns built for architectural ceramics.

SUMMARY OF THE DEVELOPMENT OF THE NORTHERN *MAN-THOU* KILN

From the evidence supplied by archaeology, it seems that the northern style of *man-thou* kiln developed from traditional cross-draught brick kilns, many of which were dug directly into loess banks. These early tile and brick kilns used the radical

[108] The authors have observed and investigated *man-thou* kilns for firing grey bricks in south China in Chiangsu, Anhui, Chiangsi, Chekiang and Fukien provinces.

principle of having firebox, kiln-chamber and exit flues built horizontally in line, rather than one above the other, as in the earlier up-draught design. Most early tile and brick kilns operated with strong reducing atmospheres at full temperatures, and during early cooling, and were used to fire grey architectural ceramics favoured in China from the Neolithic period onwards. Most northern tile kilns used wood as a fuel, but a few were adapted for use with coal or charcoal briquettes. Similar cross-draught kilns were used in the Han dynasties to fire, and then to pre-heat, the stacked ceramic moulds used in the mass-production of iron-castings.

With the revival of stoneware in northern China in the $+5^{th}$ century, small kilns of about one metre internal diameter were developed at sites such as An-yang and Kung-hsien in Honan province. These tended to be built above ground but still incorporated the well-established cross-draught principle. Firebox-to-chamber ratios were high in these kilns, partly because of their small size, but also through the need to generate the greater heat needed for stoneware and, before long, porcelain. Early stoneware kilns in north China tended to avoid the 'trident' method for joining three exit flues into a single vertical chimney flue, a structural feature seen in earlier brick kiln designs. Wood firing remained common in the north until the later $+10^{th}$ century, when many northern kiln-complexes converted to coal.

With the adoption of coal as a fuel, kiln fireboxes became smaller but the ash pits beneath the firebars were made much deeper. Most kilns now used two chimneys side-by-side with the chambers connecting directly to the chimney bases by vertical slot-shaped flues. The chimneys of coal-fired *man-thou* kilns tended to be both relatively wide and relatively short, and they narrowed towards their tops. It seems likely that the two-chimney principle was adopted to simplify construction, and also to improve evenness of firing across the kilns' widths. Their wide and generally bottle-shaped forms limited flame-speed within the kilns. Wide chimneys also improved firing efficiency as they were less likely to overheat towards the end of the cycle. *Man-thou* kilns may well have been made to operate in true up-draught mode during the firings' early stages, by uncovering holes built into the kilns' domes.

Two short wide chimneys set side-by-side, coal firing, and small and generally cubic firing chambers with domed roofs typify most northern high-temperature kilns used for glazed wares in north China from about the $+11^{th}$ to the mid $+20^{th}$ centuries. The true down-draught design (the logical extension of this principle) seems a recent introduction to north China, perhaps from Western practice.[109] Cross-draught kilns are inherently uneven in their finishing temperatures, and very long firings seem to have evolved in the north to counter the problem to some extent, by encouraging conduction within the settings. Because of the trade-off that is possible between time and temperature in ceramic reactions, the actual finishing temperatures within these kilns may have been significantly lower than the refractoriness of their glazes and bodies seem to suggest. Nonetheless, and despite the

[109] Garnsey & Alley (1983), pp. 29–30, illustrate modern kilns in Shansi province of typical Western down-draught type.

relative inefficiency of this firing process, the low-flux and high-alumina natures of most northern refractory clays would have benefited from long soaks at high temperatures. That promoted mullite development, with its consequent gains in toughness and fired strength.

Setting Techniques and Kiln Furniture for Northern Kilns

The main aims for potters setting ceramic kilns are the production of sound wares, the encouragement of even firings, and the economical use of fuel. These are universal concerns for potters throughout the world, and must have been addressed in north China as early as the Neolithic period. The thousands of Chinese Neolithic wares that fired successfully and have survived show that accurate control of kiln temperatures and kiln atmospheres were achieved, though no detailed evidence exists on how these wares were originally set. Nonetheless, when placing unglazed wares in up-draught kilns, simple rules soon emerge from practice: small pots can be set inside larger pots; covers can be fired in place; and it is not too important which way up the wares are stood. Larger wares survive better if surrounded by smaller wares, as larger forms are less likely to crack from uneven heat if they are placed towards the centre of the setting. In general too, denser packing tends to be more effective than a looser set as it reduces flame-speed and improves heat distribution, both from conduction by the wares and through some baffling of the flames. Denser settings also tend to be more economical in terms of kiln yield. In the case of grey wares and carbonised wares, which were typical of later Neolithic Chinese ceramic production, closer packing also discouraged reoxidation and helped reduction.

When packing an up-draught kiln, raw wares can usually be piled safely one upon the other to a height of about one metre. It is often helpful if the stacks of wares are steadied and parted with occasional 'trigging', usually in the form of fired sherds. When no glazes are used, contact between objects does not present a problem. Common sense, for example the avoidance of placing too much weight on small, thin wares, improves survival rates. No custom-made kiln furniture is known from north Chinese Neolithic kiln sites, and the small scale of northern Neolithic kilns may have made its use unnecessary.

Shang Dynasty Setting Practices

Even with stoneware firings practised for Shang dynasty whitewares in north China, these same setting principles may well have applied. The white clays used were quite refractory, and fired below the temperatures at which pronounced firing shrinkages and pryoplastic distortions tend to occur. Their unglazed nature too would have simplified setting.

In the case of the other great Shang dynasty ceramic innovation in north China – ceramic moulds used for bronze-casting – the prime consideration was to

avoid distortion in drying and firing. Surviving Shang dynasty bronzes show how fine were the tolerances expected from the moulds, as it is often hard to see on the finished bronzes how the separate moulds-sections were arranged. This suggests that multiple-section casting-moulds may well have been fired in an assembled state. This would have ensured that any differences in firing treatment affected adjacent sections of the mould, making accurate reassembly at the foundry more certain. The same principles would have applied throughout the Bronze Age in north China. Even the production of moulds for stack-casting iron involved accurately made ceramic piece-moulds.

HAN DYNASTY GLAZED WARES

With the arrival of glazed wares in north China, new problems arose in setting. Particularly difficult was how to prevent wares from sticking together as their glazes melted in the kiln. In this case the wares themselves provide clues to the setting methods used. For example, the flow of their glazes shows that most large Han dynasty lead-glazed vessels were fired upside-down, separated with dots of red clay. In many cases these small clay separators remain fused to the vessels' rims, and sometimes to their bases.

A possible motive for firing large lead-glazed vessels upside-down may have been to protect their contents (probably smaller glazed wares) from the debris of exploded pots. Steam explosions are not uncommon when firing raw wares, and the debris tends to ricochet through the kiln, often landing in open vessels, where stuck fragments of clay spoil the glazed surfaces. It seem likely that most Han dynasty lead glazes were applied to raw wares, unlike Thang dynasty lead-glazed wares which were often given initial biscuit-firings. The judgement that many Han dynasty lead-glazed wares were once-fired, is suggested by the fact that many examples show patches of darkened, reduction-fired clay beneath their glazes. This is a classic sign of raw glazing, and a process that exposed the glazes to damage from exploding wares.

THANG DYNASTY *SAN-TSHAI* WARES

On *san-tshai* wares the flow of lead glazes on large jars, bottles and flasks shows that these were fired the right-way up, as were most figurines. This would have been a safer practice than with Han dynasty pots, as biscuit-fired wares very rarely explode in glaze kilns.[110] Thang dynasty *san-tshai* dishes often bear three small scars from the points of triangular setters or fine arc-shaped scars from setting rings. These show

[110] 'Tang sancai [Thang san-tshai] were fired twice. The biscuit-firing temperature was about 1,050°C for utensils and slightly lower for tomb figurines . . . The glaze firing was carried out in a kiln of moderate size using oxidizing flame at a temperature below 900°C.' Li Zhiyan & Zhang Fukang (1986), p. 76.

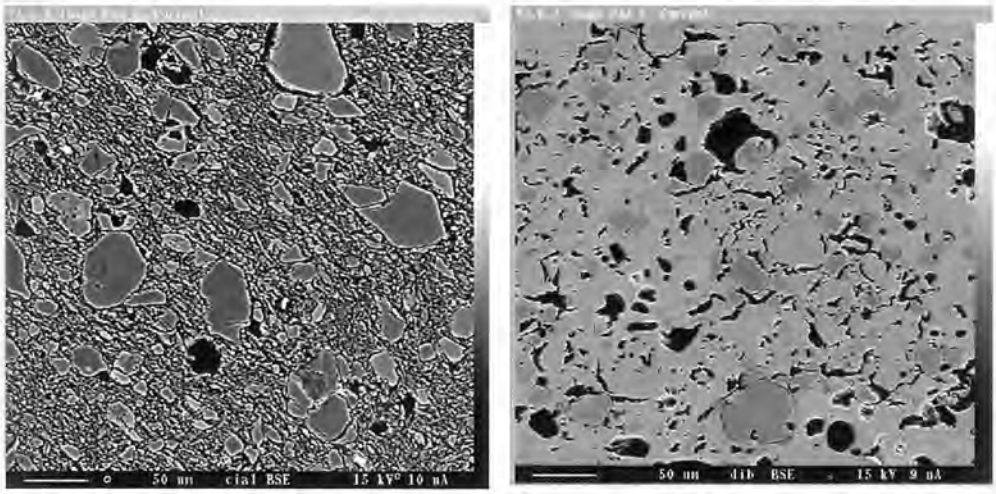


Fig. 81 Microstructure of Thang dynasty northern stoneware (left) and Thang dynasty translucent northern porcelain, possibly Hsing ware (right). From the mid +9th-century shipwreck, found near Belitung in Indonesia. Although fired to comparable temperatures the low-flux whiteware shows little body-glass development, while the porcelain example on the right shows both abundant body-glass and softening and merging of the clay + quartz groundmass

that they have been stacked one above the other, and simply parted with reusable clay props.[111] Of all Chinese glazed wares, *san-tshai* would have been the easiest to set and fire as they were toughened by their biscuit-firings and shrank no further when fired to glaze temperatures. Northern stonewares and porcelains, by contrast, would have been a far more difficult prospect to pack and fire safely despite being made from virtually the same clays. This is largely because of the higher firing shrinkages and tendencies to distortion associated with stoneware and porcelain production.

Early Setting Methods in High-temperature Kilns

At the temperatures that *san-tshai* wares were fired to (c. 950–1,050°C) little shrinkage of the clay body occurred in the kiln. The same clay, by contrast, when fired to stoneware and porcelain temperatures would shrink substantially over the last 300°C of firing. Porcelain in particular shows as much as 10% linear shrinkage (30% volumetric) during this final maturing stage. The firing behaviour of a clay comparable with those used in north China (in fact an English high alumina ball clay, Anglo No. 4) is shown in Figure 82.

[111] Tu Pao-Jen & Cho Chen-Hsi (1987), p. 21: 'many of the triangular supports were stained with sancai [*san-tshai*] glaze dripped during firing.' See also Li Zhiyan & Zhang Fukang (1986), p. 75, fig. 13.

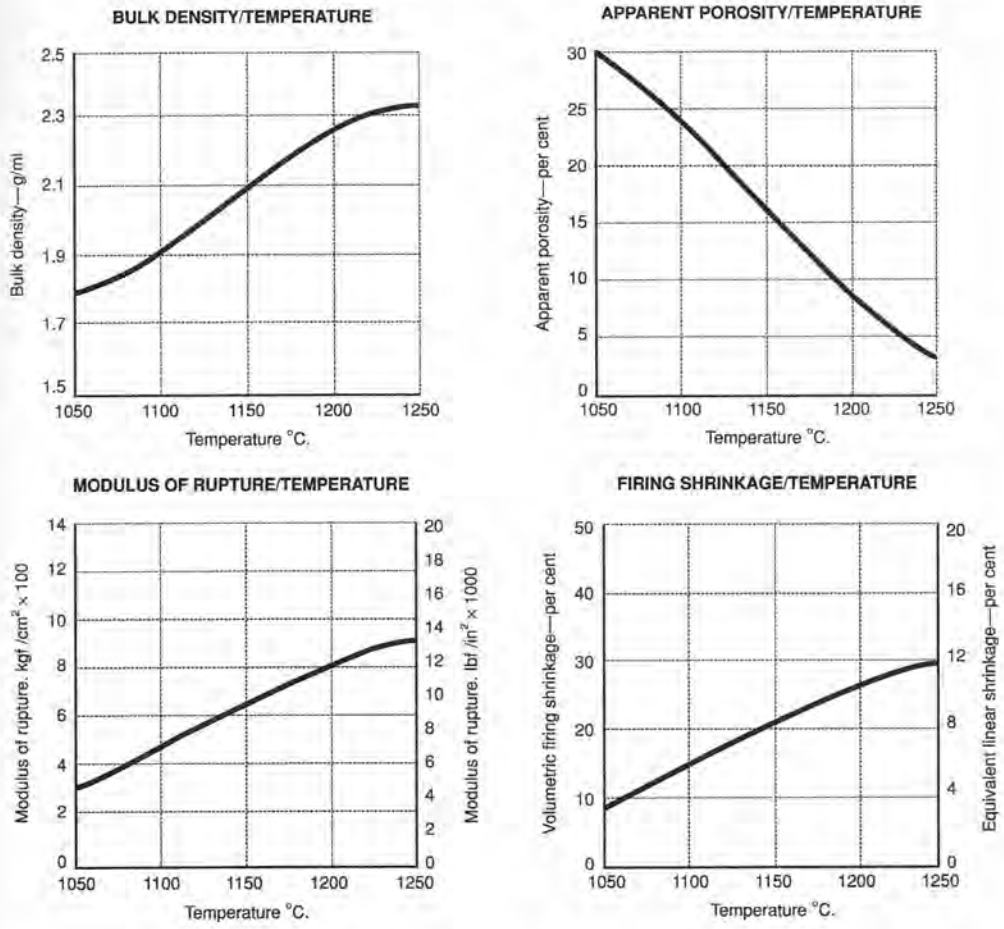


Fig. 82 Firing behaviour and fired properties of a high alumina English ball clay, similar to a north Chinese stoneware clay

These graphs show clearly the following features of this type of clay:

As kiln temperatures rise the clay's porosity decreases as the material's interstices fill with glass and the clay contracts. In this typical example fired porosity drops from 30% at 1,050°C to 4% at 1,250°C.

As kiln temperatures rise so does the clay's shrinkage. From about 20°C to 1,050°C the clay shrank only 2–4%. In the last quarter of the firing (1,050–1,250°C) the clay shrank an additional 7%, with fired strength increasing almost exactly in step with firing shrinkage.

Shrinkage during firing depends mainly on the generation of body-glass, which dissolves some of the finer body-material, together with the edges of larger mineral-grains. This causes clay bodies to consolidate, and the wares themselves to contract (Fig. 81). The change from spinel to mullite also involves some shrinkage of the

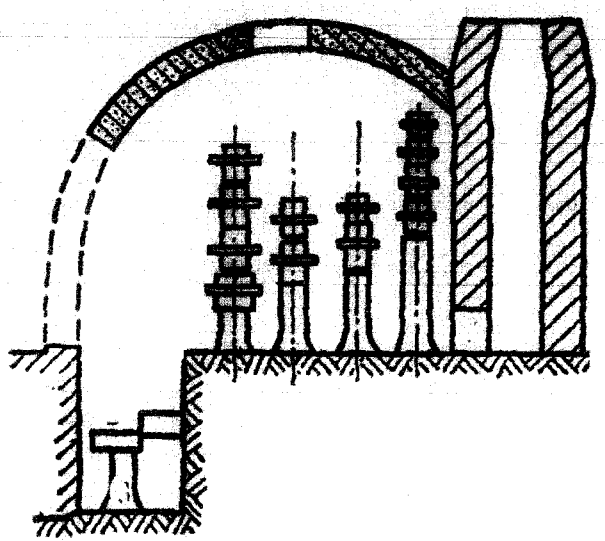


Fig. 83 Kung-hsien cross-draft kiln of the Sui to Thang period showing a setting arrangement that rose towards the back wall of the kiln. This was designed to compensate for the fall-off of heat that occurred near to the exit flues

body as the alumino-silicate crystals rebuild their forms. A further effect of this process is the way that body-glass plays a role in white-hot ceramic, similar to water in plastic clay. Body-glass allows clay to distort under pressure, or simply from its own weight if the forms are not sufficiently strong. This means that low-glass Chinese glazed earthenwares can be stacked with some impunity, provided simple separators are used to limit contact between glazed surfaces. Stacks of stoneware and porcelain will not only distort, but also tend to fuse together and collapse, if not properly separated and supported in the kiln.

Perhaps the most obvious sign of these effects occurs in the way that the rims of stoneware and porcelain bowls become very crooked if their feet cannot contract evenly over the last 100°C of firing. This happens because any distortion of the base tends to transfer to the whole form as the object becomes soft at high temperature. As bowls were the main products at most Chinese kiln sites many strategies were evolved to cope with this phenomenon. Any method used had also to take into account the tendency of high-temperature *clays* to stick together somewhat where they were in contact, again due to the formation of ample body-glass. In wood-fired kilns these sticking effects were compounded by fly ash, which covers the whole kiln setting impartially with a very thin coat of glaze.

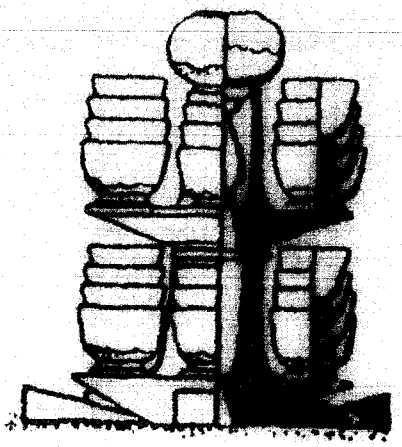


Fig. 84 Setting methods used for stonewares in Kuangsi province in the Sui dynasty

A good image of how setting methods for high-fired wares evolved in north China has come from study of the Hsing kilns 邢窯 in Hopei province, where a change from greenware to whiteware occurred in the Sui dynasty. These very early northern high-temperature wares were open-fired in wood-burning kilns of early *man-thou* style, using ingenious 'cakestand' supports that consisted of thick round shelves set on tall hollow columns. The stacks of bowls were separated by flat triangular clay and the bases of the wares were unglazed. Although the three supports with three raised points of the setters rested on the glazed insides of the bowls, these contact marks could be chipped clean after firing.

Besides permitting a reasonable density of setting, this arrangement also allowed large jars to be fired at the top of the stacks. A further advantage of the method was that the flaring round shelves on which the wares were placed could be arranged to start at heights that avoided the cool areas of the kiln, particularly the bottom-back, near to the exit flues.[112] These somewhat precarious tall stacks were steadied by thick fireclay wedges at floor level (see Fig. 83). Problems may well have arisen from the stacks' leaning towards the fireboxes during firing, as the shelves and supporting columns contracted more on their hotter sides. Remarkably, the same setting method has been reported for firing small Sui dynasty cups of similar form some 1,500 kilometres south, in Kuangsi province. In this case the stands were placed on top of bungs of saggers (Fig. 84).[113]

[112] Bi Naihai & Zhang Zhizhong (1989), p. 466.
[113] See Li Hua (1991), p. 86, fig 12.

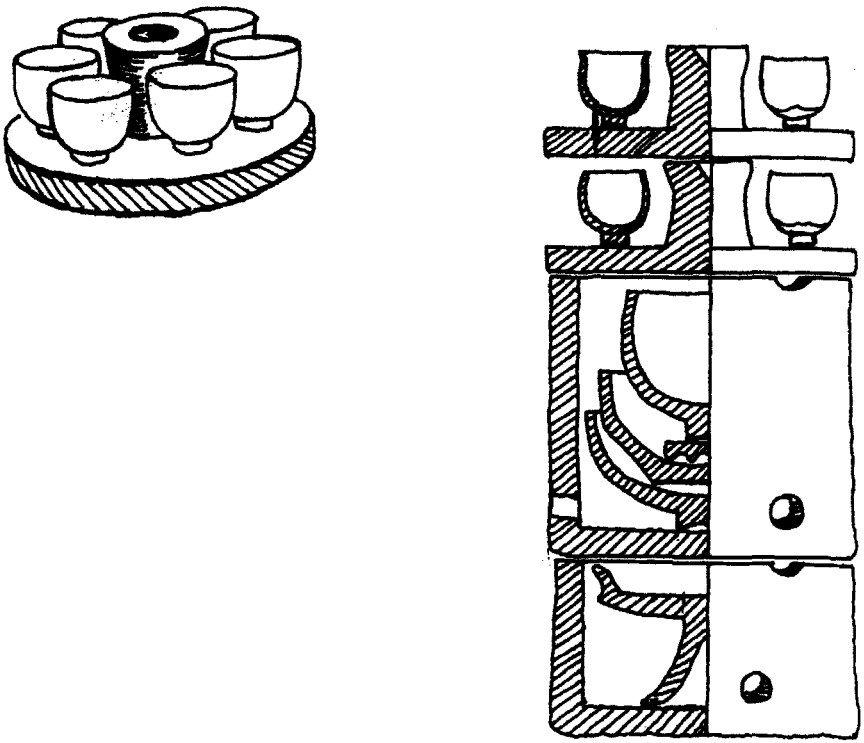


Fig. 85 Late Sui to early Thang dynasty technique for setting Hsing wares

It seems likely that early Hsing whitewares were once-fired, and that the triangular setters placed between the bowls cups and dishes were used only once. Single use of parting pads is an ideal approach in high-temperature production as the raw supports shrink in step with the bowls they are supporting, keeping the feet round and the rims true. The Hsing kilns also used simple thrown columns to support stacks of bowls, sometimes with the bowls placed the right-way-up, sometimes upside-down. The latter arrangement perhaps gave better protection from wood ash, roof debris, and fragments of exploded wares. This column-and-parting pad system had already been used in south China, but with round rather than with triangular supports. It seems that use of triangular supports followed the familiar north–south divide in China, with some outliers in Szechuan province. Their adoption apparently radiated outwards from kilns in central Hopei province. As the chart shows two styles of triangular setter were used, one with points on one side only, the other on both.

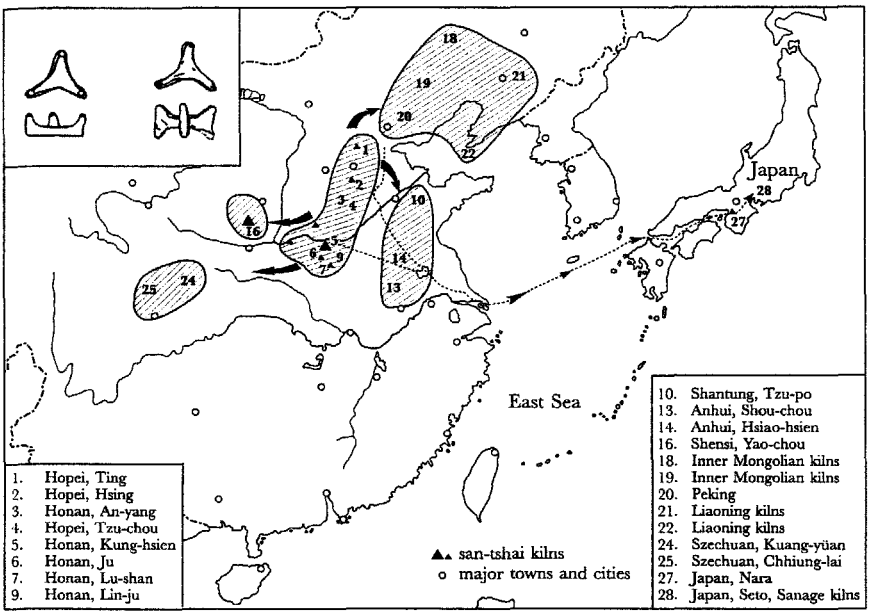


Fig. 86 Spread and distribution of the triangular kiln-setting support in China

Archaeologists place the introduction of the second type to kilns at Chieh-hsiu 介休 in Shansi province, in the Northern Sung dynasty:[114]

After firing, only three small pin marks would remain on both the bottom surface and inner bottom surface of the ware. This was the peak of the development of the triangular cake.

SAGGERS

The double-sided triangular parter, used so effectively throughout both north China and in Szechuan province, is still a useful aid to firing craft and industrial ceramics world-wide. This is true too of another great kiln setting innovation, the sagger. Saggers are fired clay boxes (usually cylindrical) into which raw or biscuited wares can be packed, with the loaded boxes built into tall columns or 'bungs' within the kilns. Saggers solve many problems simultaneously and have proved one of the greatest boons to ceramic production. Their use has been shown to be extremely ancient in ceramic history, dating to at least the late -3^{rd} millennium, when 'bungs' of thrown saggars were used by the Indus civilisation of northern India for firing

[114] Shui Jisheng (1986), p. 307.

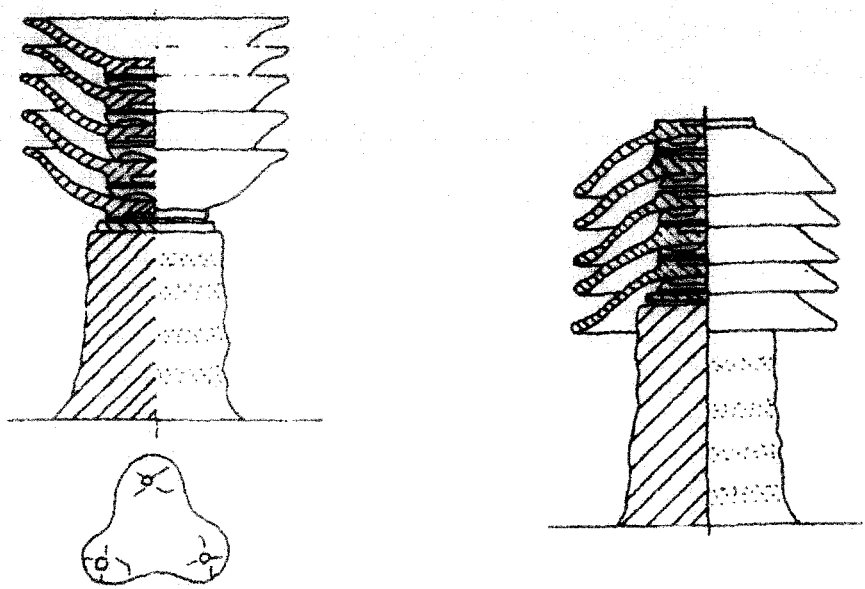


Fig. 87 Setting methods used for many Sui and early Thang dynasty stonewares and porcelains in north China

bangles.[115] In China their first recognisable use appears more than 2,500 years later.[116]

In detail, saggers:

- protect the wares from coal or wood ash
- contain the effects of any explosions of wares
- protect the wares from cooling draughts
- encourage even heat distribution throughout the kiln, both through their mass and through the uniformity of the settings that they allow
- allow more thorough filling of the kiln space by avoiding the use of unstable stacks
- allow taller kiln-chambers to be built and exploited

In China, as well as in other countries of the world, saggers also allowed an economical, if somewhat gruelling, practice: workers were enabled to dash into the kiln while it was still cooling down, grab a sagger and then run out again. By this method

[115] Vidale (1990), pp. 240–6.

[116] There are reports from China that saggers have been found associated with the production of fine Lungshan Neolithic 'eggshell' wares in Shantung province, but they remain to be confirmed. The earliest saggers from excavations cited to date are of early +4th-century date, see pp. 343 and 524.

kilns could be emptied quickly and then reset while still very warm, thus saving time and fuel for the next firing.

Saggers can be used numerous times and made in many shapes and sizes to accommodate different wares. Their use became particularly important in north China in the +10th century when the gradual adoption of coal firing made the open-firing of fine wares impractical. Refractory coal ashes were far more damaging to exposed glazes than flux-rich wood ashes.

Although the concept of firing small wares within larger and sturdier vessels had probably been used in China since the Neolithic period, reusable custom-made firing containers proved an enormous boon to ceramic production in the early Northern high-temperature kilns. Simple 'bucket-shaped' saggers seem to have been introduced to north China for firing Hsing wares in the late Sui dynasty,[117] but true cylindrical saggers were already in use at this time in Kuangsi province.[118] Opinions differ as to whether any use of saggers in south China anticipated these dates. Eastern Chin dynasty saggers from the Hung-chou kilns 洪州窯 in Chiangsi province and the Hsiang-yin kilns 湘陰窯 in Hunan province are mentioned (see note 116, p. 342), but southern cylindrical supports for stacks of bowls can appear very sagger-like, and have even been proposed as the origin for southern saggers.[119] There is also the consideration that unglazed stoneware vessels were important parallel productions with glazed stonewares at many early southern kilns. The unglazed vessels would have made useful temporary containers for firing finer glazed wares, a concept that could have led naturally to specially made, reusable saggers. At Hsing kilns of the late Sui dynasty, the 'pillars and setter' method of firing bowls still tended to be used in parallel with these 'bucket-shaped' saggers, with the latter used mainly for supporting and protecting tall vases and jars.[120]

A late Sui dynasty Hsing ware sagger from Nei-chhiu 內丘 is described as having its 'characteristic phase the same as white porcelain',[121] so it may be that similar clays were originally used for both saggers and wares. However, as saggers are fired numerous times to high temperatures their glass contents tend to rise with use, and they also suffer exterior attack from fly ash. For both reasons their strength under load eventually becomes unreliable, and they have to be retired, although many would have cracked and been scrapped before they reached this state.

Because of the technical demands made on saggers it soon became the practice to make them from more refractory clays than the wares they contained. This became especially important when thorough reduction-firing of glazes was necessary: if sagger materials are too vitreous they tended to block the ingress of reducing

[117] 'At the end of the Sui dynasty, in order to fire white porcelain wares, the craftsmen of Xing [Hsing] ware invented [the] bucket sagger.' Bai Naihai & Zhang Zhizhong (1989), p. 266.

[118] Li Hua (1991), p. 86.

[119] Lao Fasheng, Ye Hongming & Cheng Zhuhai (1986), p. 319, write, concerning Chekiang province: 'In the period of the Tang [Thang] dynasty . . . the cylindrical setters were changed into saggers, accordingly the firing of porcelain wares were changed from open firing to firing in saggers.'

[120] Bai Naihai & Zhang Zhizhong (1989), p. 467.

[121] *Ibid.*

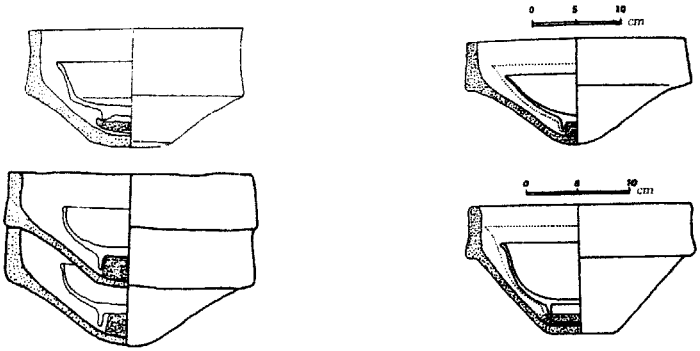


Fig. 88 Funnel-shaped saggers with bowls and stacked bowls inside

gases, such as carbon monoxide and hydrogen, to the detriment of glaze colour. Even when their first use as supports for wares was finished, old saggers were often recycled for kiln building, for use in kiln grates, or for the walls of houses and workshops.

Some of the first saggers specifically designed for firing individual bowls come from kilns making Hsing ware at Nei-chhiu, and date to the early Thang dynasty. They had dished, rather than flat bases, into which the curves of the bowls fitted. The dropped base of the next sagger fitted inside the bowl beneath (without touching it) and so on. This allowed a far greater density of setting than was possible with cylindrical saggers, and it also meant that the insides of the bowls were unmarked by setting scars. However, it was still necessary to place setters between bowls and sagger bases, to assist the even shrinkage of the wares, as well as to facilitate the separation of the bowls from the saggers after firing.

The disadvantage of the funnel-shaped sagger was the sheer mass of material used to make it (compared with the bowl that it contained) and the consequent energy that it absorbed in firing with a 5:1 mass ratio between sagger and bowl being quite typical. Even so, this did not prevent funnel saggers from being used right across China, from the early Thang dynasty down to the present day.

Very similar funnel-shaped saggers, for firing plates and bowls, are still used at European porcelain factories such as Limoges in France, although these are now made from highly conductive and refractory materials such as silicon carbide (SiC).[122] A variation of the funnel sagger was made with a cross-sectional 'M' shape and this slightly lighter version saw use in kilns as widely spread as Yao-chou in Shensi province, and Shang-lin-hu 上林湖 in Chekiang province.[123]

[122] Appropriate uses for new materials in the +20th–21st centuries, of which this is a good example, are further discussed in Part 7, pp. 782–92.

[123] Observed at both Huang-pao and Shang-lin-hu by the authors.

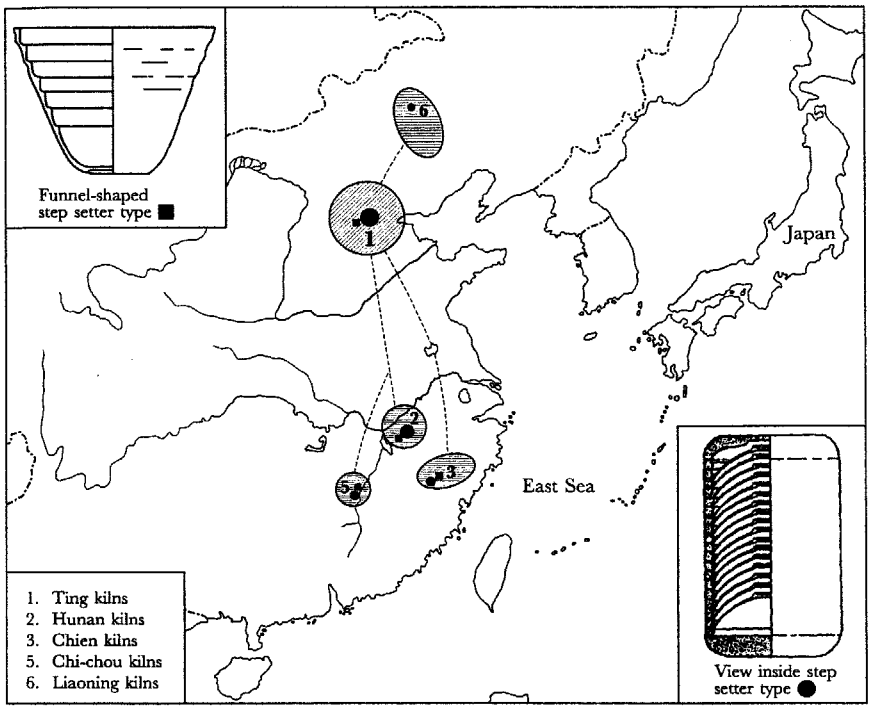


Fig. 89 Spread of the step-setter technique

STEP SETTERS

More economical use of both funnel and cylindrical saggers could come from stacking three or four bowls per sagger, although a proportion would then show setting scars. The most original and economical development for firing bowls and dishes ever devised in north China appeared at the Ting kilns 定窯 in the Northern Sung dynasty. This was the step setter. The step setter was essentially a thick bowl with its inside surface ridged with a series of fine steps. A number of bowls of increasing diameter could be set rim-down on these ledges, and both setter and bowls placed within a heavier fireclay saggers. Step setters were used only once and were made from similar clays to the wares they supported. They shrank with the bowls during firing, keeping the bowls' rims round and their forms true. For the method to work successfully the rims of the bowls and dishes had to be left unglazed, a flaw that was often disguised after firing by the fitting of deep metal bands (see p. 696).

It is possible to see the origins for this *fu-shao* 覆燒 (upside-down) method at the Hsing kilns where an early type of rim-down setting method had been devised,

using saggers with L-shaped cross-sections for firing bowls. These heavy L-sectioned rings appear to have doubled as both saggers and setters.[124] Much finer ring setters made from porcelain clay were developed at the Ting kilns, but for single use only, and for placing within much heavier reusable saggers. These allowed as many as twenty identical bowls or dishes to be fired upside-down, one above the other, in the same stack (Fig. 89). The most sophisticated *fu-shao* firing methods at the Ting kilns seem to have surmounted bowl-shaped stepped setters with stacks of supporting rings. Once assembled, the outsides of the setter-and-bowl stacks were brushed lightly with slip to serve as a temporary bond, and placed inside heavy fireclay saggers. This arrangement gave a quite remarkable setting density within the kilns. The *fu-shao* method of packing saggers spread from the Ting kilns to a number of northern Tzhu-chou kilns in the Chin dynasty, such as Kuan-thai in Hopei province,[125] and Pa-tshun 霸村 in Honan province.[126] It also travelled south to Ching-te-chen and to kilns in Fukien province in the Southern Sung dynasty.[127]

[124] Bai Naihai & Zhang Zhizhong (1989), p. 470, fig. 10.
[125] Anon. (1997d), p. 478.
[126] Observed by NW at Pa-tshun in +1995.
[127] Liu Hsin-Yuan (1980), pp. 53–5, trans. Tichane (1983), pp. 394–416.

DRAGON OR *LUNG* KILNS

While the *man-thou* kiln can be regarded as the classic northern kiln design, the *lung* 龍 or dragon kiln became the definitive southern type. The dragon kiln was essentially a narrow tunnel built up a low slope. Fire burned at the bottom end of the kiln and the wares were stacked from the floor of the tunnel, either on shallow steps, or with their supports steadied by a bed of quartz-grit. Because of its slope the dragon kiln could act as its own chimney, and wood, with its usefully long flame, was its main fuel. Distribution of dragon kilns in China tends to fall below the north–south divide, with particular concentrations in the south-eastern coastal regions (see Fig. 90).

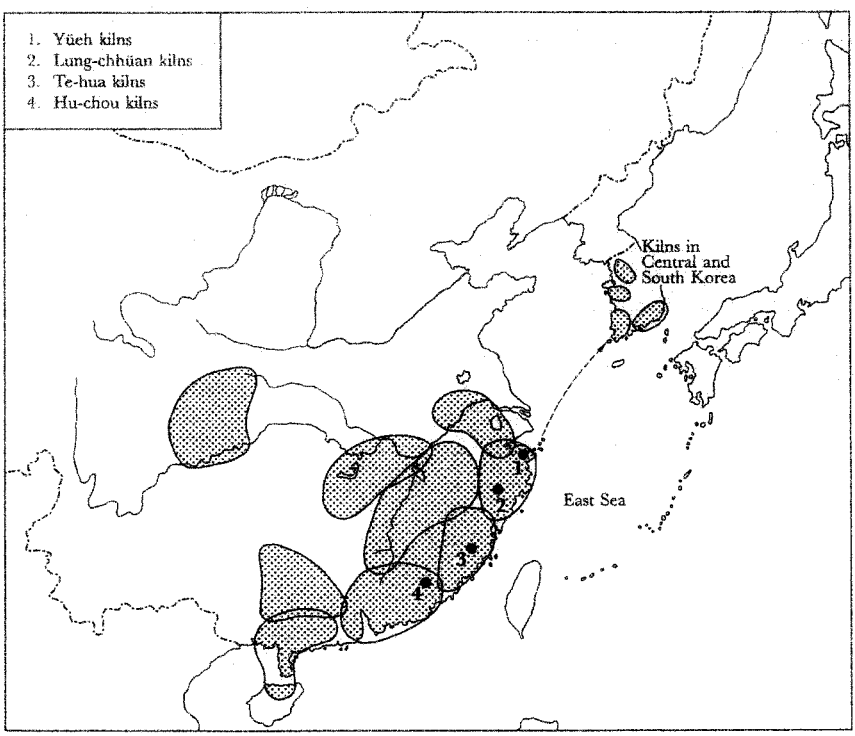


Fig. 90 Distribution of dragon kilns in south China and Korea over the last two millennia

Although dragon kilns use similar cross-draught principles to *man-thou* kilns they differed from the northern kilns in almost every other respect. For example, the structures of developed southern dragon kilns could be huge, up to 135.6 metres in length by the late Northern Sung dynasty.[128] This made dragon kilns capable of firing some tens of thousands of vessels in one setting, rather than the few hundred objects typical of a *man-thou* firing. Despite their size, the firing times for dragon kilns could also very short, for example 24 hours might be a typical firing duration for a 'small' dragon kiln, some 30 metres in length.[129] Wood rather than coal was the main fuel for dragon kilns, and soaking times at top temperatures, for the separate zones within the kilns, could be measured in minutes rather than hours. Dragon kilns did share with *man-thou* kilns some problems with uneven firing, however, and much of their development was concerned with ameliorating the problem.

ORIGINS OF SOUTHERN DRAGON KILNS

The origins of southern dragon kilns seem closely associated with the appearance of southern glazed stoneware. The earliest kilns yet found for firing these wares have been excavated at Wu-chheng 吳城, an important Bronze Age ceramics-producing site some 120 kilometres south of Nan-chhang 南昌 in Chiangsi province, and at Shang-yü 上虞 in Chekiang province, a kiln area later famous for its Yüeh 越 greenwares. Wu-chheng has been proposed as a major source of northern finds of early glazed stoneware, such as those excavated with hoards of ritual bronzes from mid Shang dynasty levels at Cheng-chou.[130] Similar wares to those found at Cheng-chou have been excavated from Wu-chheng, where about 17% of the ceramics from Shang dynasty levels were of the glazed high-fired type.[131] Archaeologists cite Shang-yü as being another major source of early, glazed, high-fired wares, a type of product that the region continued to manufacture for more than 2,000 years.

Four long-section kilns were excavated at Wu-chheng, the best preserved of which is 7.15 metres long and 1.02 metres wide. Its surviving base is almost level, the top being only 0.25 metres higher than the bottom end. It has nine 'entrances' along one side that may have been for fuel. Its operation as a kiln is rather difficult to interpret from its plan. Its slope is minimal, so the direction of its draught is unclear, and the stoke-holes (if this is what they are) seem unusually closely set. Both high-fired glazed ware and stamped pottery were found at this site, which appears to have been one of the most important mid Shang dynasty production centres for glazed stoneware in south China. The ceramic remains indicate that firing temperatures in the kiln exceeded 1,200°C.

[128] Zeng Fan (1997b), pp. 30–1.
[129] Anon. (1933), China Industrial Handbooks, Kiangsu, p. 805.
[130] Yuba (2001), pp. 52–3. See also pp. 11–12, 129–30 of this book.
[131] Li Yü-Lin (1989), pp. 79–81, 58.

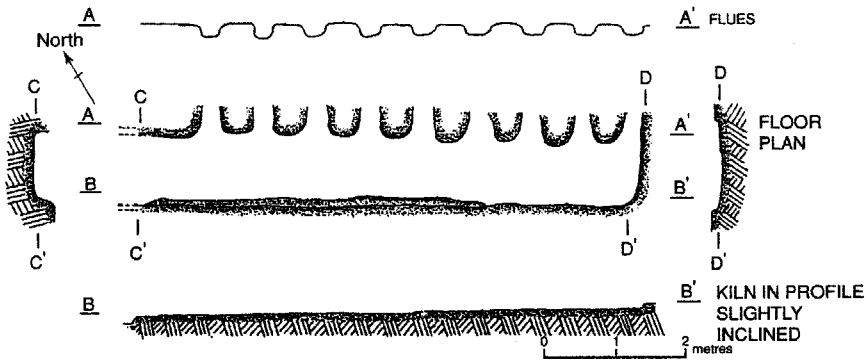


Fig. 91 Three views of a Shang dynasty high-temperature kiln from Wu-chheng

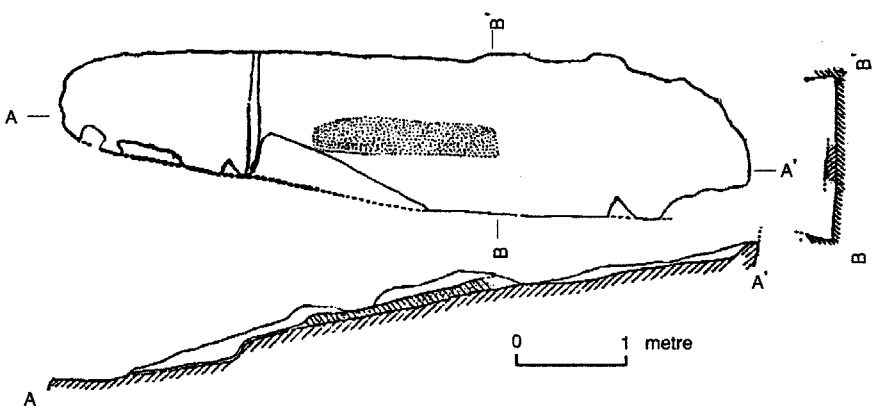


Fig. 92 Shang dynasty dragon kiln from Shang-yü

The structure at Shang-yü is rather more recognisable as a dragon kiln. In this case the surviving bed of the kiln is clearly separated into firebox and ware chamber, and the whole kiln slopes at angle of about 16°. The entire kiln is 5.1 metres long and 1.22 metres wide at its widest point, with the ware chamber situated 0.2 metres higher than the firebox. Judging from the kiln's remains there seems no facility for side-stoking, although any stoke-holes may have been placed higher on the superstructure, which is now missing. The kiln was evidently a major producer of hard, stamped ware, whose glazes bore signs of natural 'blistering' from a hot kiln that was firing to 1,200°C or above.[132]

[132] Hsü Hai-Thang (1995), pp. 82–4.

This Shang kiln at Shang-yü is of enormous importance, not only for the history of Chinese ceramics, but also for world technology in general. Chinese glazed stonewares of the mid Shang dynasty began China's great tradition of high-fired glazed ceramics, and kilns essentially similar to the Shang-yü structure have been used continually in the south for more than 3,000 years. This simple concept of an elongated sloping kiln-chamber was not adopted in the West until the +13th–14th centuries for firing Rhenish stonewares,[133] while other East Asian versions of the Chinese dragon kiln were mainly derived from China, and often established by Chinese émigré potters.

At the time of writing, news of the excavation of ten high-temperature kilns, of middle to late Shang dynasty date, at Chiao-shan 蛟山 in Chiangsi province, seems set to revolutionise our understandings of early Chinese kiln design. The site was explored by the Archaeological Research Institute of Chiangsi province 江西省考古研究所 and the ten Shang kilns include examples of both the dragon and the 'proto-*man-thou*' types.[134] This may make more likely the spread of the cross-draught kiln style to north China from the south, albeit for firing earthenwares rather than glazed stonewares in its northern form. Many pottery-making tools were also found at the site, some bearing written inscriptions and the site's investigators hope to expand this important excavation over the next three to five years.

As to the origins of the dragon kiln form, in some ways it echoes that of the early architecture of China. In the north, Neolithic houses were often semi-subterranean, with their floors dug into the soft loess. Northern Neolithic kilns initially followed this semi-subterranean trend, with later Neolithic kilns being completely excavated from loess banks. The floors of southern Neolithic houses by contrast were often raised from the ground, partly to avoid four-legged and multi-legged pests, as well as snakes and damp. So far as can be assessed, southern Neolithic wares were often fired direct on the ground, perhaps because the harder and rockier surfaces were less suitable for excavated kilns. It is perhaps from such surface-built kilns that the southern dragon kilns evolved.

Southern glazed ceramics flourished in the Western and Eastern Chou dynasties, with their production spreading from a nucleus in southern Chiangsi–western Chekiang, into Anhui, Chiangsu, eastern Chekiang, Fukien and Kuangtung provinces.[135] The styles of kiln used seem similar to the Shang dynasty kiln at Shang-yü, with a Warring States example being found at an ancient site for ceramic production in a fertile and hilly part of northern Chekiang province. This kiln was built on a gentle slope some 300 metres south of Fu-sheng 富盛. The Shao-hsing Cultural Relics Committee 紹興縣文物管理委員會 reported the find in +1979:[136]

[133] For example, see the photograph of the excavated floor of a Rhenish stoneware kiln, *c.*+1400, in Gaimster (1997), p. 126, fig.5.
[134] Anon. (2001, *People's Daily*).
[135] Chiang Tsan-Chhu (1998), p. 325.
[136] Anon. (1979e), p. 231.

Across the rice fields from the site, the remains of two kilns 3.5 metres apart were found. In each kiln a total of five layers of kiln beds were unearthed, the result of building a new kiln on the remains of the old one. Between the layers sherds of primitive celadon, high-fired earthenware with impressed geometric designs, spurs and even broken pieces of the kiln roof were found . . . A trial excavation proved that high-fired earthenware and primitive celadon had been fired together.

The kiln at Fu-sheng had a floor-angle of some 16°, while its length was estimated at 6 metres, and its width at 2.4 metres, rather wider than the Shang dynasty example described above. Nonetheless, as the report's authors show, this Warring States dragon kiln had its drawbacks:[137]

This kiln is less systematic in plan and more primitive in construction than later dragon kilns. For example the kiln is less than 6 metres long, but the kiln bed itself, excluding the firebox and smoke hole, is only about 4 metres long, and has a small production capacity. Moreover, the firing chamber is 2.4 metres wide, with the result that the flames spread quickly and were hard to concentrate, producing uneven temperatures inside the kiln . . . Also, since the chamber is overly wide and the roof arches too broad, the high temperatures inside the kiln made the roof collapse before it had been used for very long.

The four-metre setting-chamber of the Fu-sheng kiln was about the maximum length that could be fired without side-stoking and shows the unfavourable ratio of combustion area to setting-space that tends to operate in small kilns. By the Eastern Han dynasty, typical dragon kilns in Chekiang province were about thirteen metres long. These must have been side-stoked, and this principle deserves some study in detail, as it gave rise to spectacular thermal efficiency.

SIDE-STOKING

Early dragon kilns in China resembled a design that later became fixed as the Japanese *anagama* kiln 穴窯. It was a single, sloping, slightly swollen chamber, a few metres long, fired entirely by the large firebox at its lower end, and with a small exit flue at the top. A serious flaw with this design is the considerable fall-off of heat from the firebox to the chimney end of the kiln, typically from about 1,250°C to 1,000°C. At some period, probably in the Western Han dynasty, southern potters realised that, by posting fuel directly into the kiln-chamber amongst the wares, the heat could be boosted at the upper levels of the kiln, and the whole setting eventually brought nearer to a standard temperature.

A refinement to this process involved admitting air for burning the side-stoked fuel some way further down the kiln, at a zone where wares had already reached full heat. Combustion-air was heated by the cooling wares, giving an enormous boost to the burning efficiency of the fuel. This is partly due to the fact that the velocity of chemical reactions can be accelerated dramatically by raising the temperatures at

[137] *Ibid.*, p. 232.

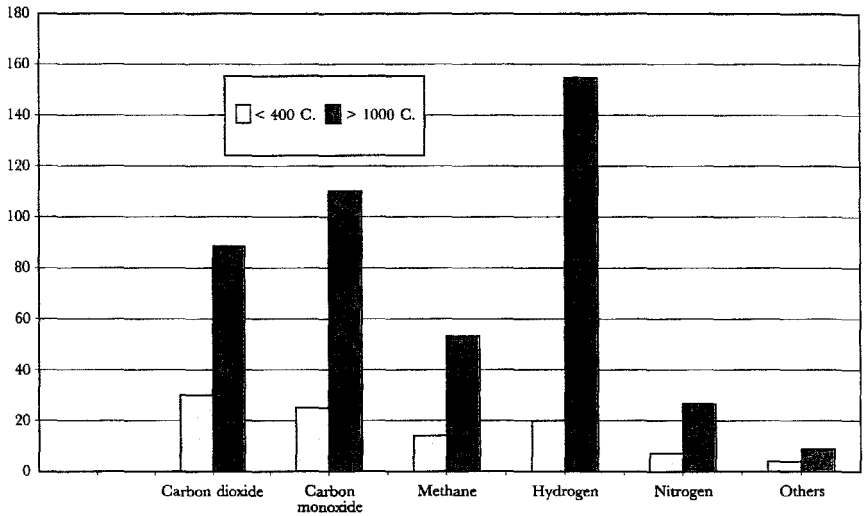


Chart 1 Balance and quantities of gases produced by wood at less than 400°C and more than 1,000°C, respectively

which they operate. As Ernst Rosenthal notes, the gains in firing efficiency through using pre-heated combustion air can be spectacular:[138]

at the temperature of 2,300°F (1,260°C) . . . a heat increase of 160% can be attained by using combustion air already preheated to 820°C.

This use of pre-heated air is also discussed by the Australian expert on wood firing, the potter Ivan McMeekin:[139]

The effect is clearly illustrated in the ease with which you can run the temperature up from 1,100°C to 1,280°C within an hour or two when side-stoking second or third chambers of a multiple-chambered kiln, with small sticks and totally pre-heated air from the first chamber. That such long dazzling white flames can be produced from two or three small sticks is quite remarkable.

This very obvious difference in combustion noted by McMeekin must also be due to the fact that when wood is 'cracked' at a very high temperature, for example by insertion into a white-hot kiln, the ratio of volatiles to char rises markedly. This increases by four times the amount of gas produced from a given amount of wood (see chart 1).[140] The 'long dazzling white flames' that resulted from burning this gas

[138] Rosenthal (1949), p. 111.
[139] McMeekin (1984), p. 44.
[140] Speight (1993), p. 57.

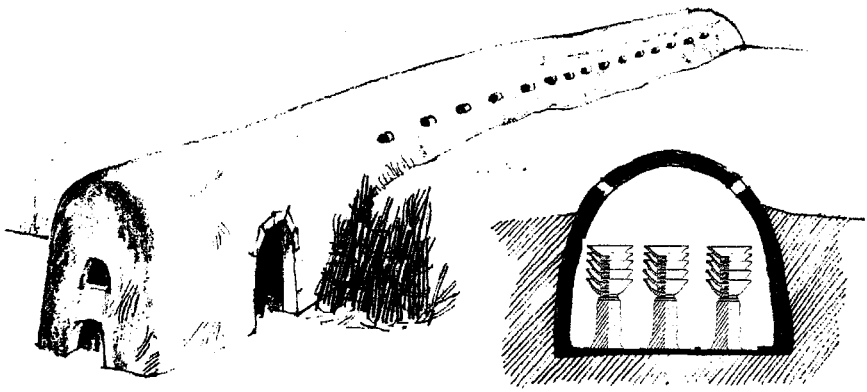


Fig. 93 Typical dragon kiln from south China, with cross-section

proved ideal for the high-temperature firing of elongated kiln-chambers, and the full-heat could be moved rapidly up the kiln through the use of successive stoking ports.

With this side-stoking refinement, there was no limit to the lengths that dragon kilns could be built, and examples more than 50 metres long eventually became commonplace in southern China, particularly for making high-fired ceramics such as Lung-chhüan celadons and *chhing-pai* 青白 and Chien blackwares in Fukien province.

This firing protocol for these kilns eventually became fixed in the following sequence:

The main firebox would have first fired the lowest area of the kiln, a few metres long, rather slowly, until this area reached full temperature. The firebox was then bricked up, with a small air-gap left. Side-stoking then commenced at the first port. When this area of the kiln reached full heat, side-stoking transferred to the next stoke-hole, a metre or so up the kiln. The firebox would then be sealed and air allowed to enter the kiln through the last-used stoke-hole. The process would be repeated until the whole kiln was fired, at which point all the ports would be sealed and the kiln allowed to cool.

Using this procedure, firing of the successive ports took place rapidly, sometimes taking as little as half-an-hour per port. A typical small dragon kiln (*c.* 30 metres) might take 24 hours to fire and 24 hours to cool down, while a longer kiln (*c.* 42 metres) might take 36 hours to fire and 72 hours before it could be unpacked.[141]

[141] A family pottery in Singapore, worked until recently by the Chuang 庄 family, provides the latter data (pers. com). In this kiln 3,500 vessels, mainly medium-to-large, took six tonnes of firewood to fire to an average temperature of 1,280°C in a 42-metre dragon kiln.

Evenness of Firing

While side-stoking was an enormous help in equalising temperatures along the length of dragon kilns, the heating of these kilns still remained uneven from roof to floor. The natural tendency of hot gases to rise, together with difficulties in setting wares in high stacks (which left considerable space at the top of the setting where flames would preferentially flow) meant that the lower parts of the settings were often badly under-fired. This was particularly true in the Warring States period when wares seem to have been set direct on the kiln's floor, which was covered by a layer of coarse quartz-grit. Some centuries later in the Eastern Han dynasty, stoneware discs and short stoneware pillars were used to raise the wares from the floor, and clear from the grit that could stick to glazes. After the Eastern Han dynasty discs with attached spikes were used and these were set spikes-down to stop them sliding. Eventually, in the Western Chin dynasty, much taller, waisted columns were made that raised wares well clear of the kiln floors. This encouraged some of the flames to find their way to the lowest levels, thereby improving heat distribution.[142] Another style popular in the Western Chin dynasty was a short thrown cylinder with its top cut into spike-like crenulations. Although cruder in design, this object was quicker to make than a disc with added spikes. A further setting refinement, intended to even the kiln's heat, was to space the ware-supports closer together at the hotter (firebox) end of the kiln, and further apart where the temperature was less, towards the chimney. All these devices were open setting arrangements, as some authors believe that true saggers were not used widely in the south until the Thang dynasty,[143] though this conclusion is debated (see p. 343).

In terms of their raw materials, some items of kiln furniture were made from similar clays to the wares themselves, while others were richer in coarse quartz-grit. Wares in the south were often separated by dots, dashes or lines of a quartz-rich suspension applied with a loaded brush, while the equivalent spacing material in the north was refractory clay. This further demonstrates the fundamental south–north, quartz-based–clay-based, divide that operates so consistently in Chinese ceramic practice.

Geography and Clays

Besides its remarkable firing efficiency, the dragon kiln was particularly suited to the geology and geography of southern China, and also to the unusual technical characteristics of south Chinese stoneware clays. In terms of geography the rocky, and originally volcanic, districts where stoneware and porcelain kilns were sited in the south, were rich in natural slopes on which dragon kilns could be built. These slopes were often unsuitable for cultivation and covered in scrub and fern, which the kilns

[142] Lao Fasheng *et al.* (1986), p. 316.
[143] *Ibid.*, p. 319.

could easily burn. Thus, initially at least, readily renewable energy sources surrounded the kilns.

There were also more subtle advantages to dragon kilns that were related to the natures of the stoneware clays used in southern China. These clays tended to be high in both silica and fluxes and they tended to develop their strengths quickly in firing through the rapid formation of body-glass. Prolonged firing could cause them to slump (soften and distort), so rapid rises towards their maturing temperatures were a definite advantage. The same clays also benefited from quick initial cooling, as their high-silica contents predisposed them to abundant cristobolite formation. The fast cooling, typical of the dragon kiln firing system, inhibited cristobolite development and discouraged this effect, thereby inhibiting dunts (cooling cracks). Also many early stonewares fired in dragon kilns used ash-glazes that were rich in calcia. These can look dull when cooled too slowly, or soaked extensively, due to microcrystals of anorthite forming in the glazes. Once again, quick firing and fast cooling were useful strategies to counter the dulling effects of lime-rich minerals.

It might be thought, as a further advantage to dragon kilns, that wood ash from the kilns' fireboxes could have been used in the ash-glazes that were standard at the time. Unfortunately little ash remains after a firing, as most ash is carried through the kiln by the draught of the fire, where it accumulates on kiln-walls, on setters and saggers, and on the wares themselves. This is especially true of side-stoking, where the fuel explodes into flame within the kiln-chamber. Most wood ash used for southern glazes would therefore have been burned separately and deliberately, and as a process separate from the firing of the kilns (see pp. 528–9).

Features of Construction

Two influences seem to have operated on the angles that dragon kilns were built. The first is that the lower, shorter section of the kiln, fired by the large main firebox, was often built at steeper angles than the main, side-stoked length of the kiln. This was probably because the kiln was less efficient in its early firing stages, when cold, and the steeper angle helped with initial heat rise. Once the kiln structure had warmed up well, this angle became too steep and the rest of the kiln, i.e. the side-stoked section, benefited from a shallower slope. By the Western Chin dynasty, after much experimentation with different angles, it was found that a rise of approximately 20° suited the lower section, and a 10° rise the length.[144]

A second influence on slope was the length of the kiln itself. Very long kilns generated the greatest draught, and overall angles of inclination tended to be lower on these large structures. Some of the very largest Lung-chhüan kilns were built diagonally across, rather than straight up, hillsides to limit their rise. Some examples too show a sideways change of direction half way up. Whether this latter feature was to

[144] See Lao Fasheng *et al.* (1986), p. 316. This practice of building with variable slopes seems to have been abandoned for most later dragon kilns, which tend to show the same angles over their entire lengths.



Fig. 94 Dragon kiln outside Ching-te-chen, +1982

accommodate the lie of the land, or to foil too powerful a draught, is not entirely clear.

Dragon kilns do not usually need chimneys, so they tend to end in perforated walls. On many, however, a further wall was built in front of this perforated end-wall, to protect the exiting gases from the wind. In some the space between the two walls was developed into a short chimney that was constructed across the full width of the kiln, and built with a rectangular cross-section. These chimneys, when used, were typically about 3–4 metres feet tall. They tended to appear on shallow dragon kiln designs, where they supplemented the kiln's natural draught and also helped prevent smoke blowing over surrounding workshops.[145]

Early dragon kilns were set and drawn from their firebox ends, with the setting proceeding backwards from the highest point of the kiln. Later designs had doorways in their sides, about one-third of the way along the kiln's length. This allowed setting to proceed from both the firebox and chimney ends, finishing at the doorways which would then be bricked up and plastered with sandy clay. The drawing of fired wares could also advance in both directions.

Side-stoked dragon kilns of simple tunnel form spread across the south of China, to Korea in Han times, and eventually to Japan. In China the design was used with great success for firing Yüeh wares 越窯, Thung-kuan wares 銅官窯, Chhiung-lai

[145] Traditional dragon kilns in Singapore tended to be built with chimneys of this style.

wares 邛崍窯, early Ching-te-chen porcelains 景德鎭窯, Lung-chhüan wares 龍泉窯, Chien 建窯 and Chi-chou wares 吉州窯, Kuan 官窯 and Ko wares 哥窯 and I-hsing 宜興窯 and Shih-wan stonewares 石灣窯.[146] In south China, most kilns measured costs in terms of wood units measured in loads (*kung* 揀), so efficient firing and kiln design were crucial to keep down costs. This was the case at private kilns, but also at official ones. For example, in +1074 an inspection accounted for the use of the annual quota of 600,000 loads of wood but not for the use of coal, and therefore only wood was supplied and the coal was resold.[147]

KILNS AT LUNG-CHHÜAN

The dragon kilns of Lung-chhüan in Chekiang province were among the most productive in China, and have been studied in some detail. Surviving modern dragon kilns in the environs of Lung-chhüan city provide useful working comparisons with excavated examples. At historical sites, all the workshop facilities tended to be focused around the kilns and were totally geared to firing. Hill slopes were dug to form shallow ditches which served as foundations for the kiln structures. In the Northern Sung dynasty kilns tended to be particularly large, ranging from 70 to 80 metres in length, and were constructed using old saggers, clay plaster or just earth from the hill. In plan they were slightly curved rather than straight, showing a faint 'S' shape. In the Southern Sung dynasty, kilns were shorter, about 30 to 50 metres long, and were built with old saggers and bricks. In plan they were straighter, and archaeology reveals that they had stoke-holes placed near or just above doors rather than in the kiln roof. Excavation has also revealed the facilities that existed around the kiln structure itself: a working space just in front of the fire-box; buttresses along the kiln walls; exposed or covered drainage ditches at the base or down the sides of the kiln to prevent landslides from excess rainwater; and a shelter built over the kiln to minimise effects of rain on kiln temperature. A tall chimney stood at the top end, or a lower rectangular chimney whose mouth could be shielded by old saggers stacked on top for better control of the kiln atmosphere.

In the Northern Sung dynasty, Lung-chhüan mostly did not use saggers (except for some bowls and plates), but tubular supports with clay wad separators, a traditional method used in kilns in Chekiang province in earlier periods. Late Northern Sung dynasty separators became complete discs, which were neater and left fewer marks on vessels. By the late Southern Sung period there were more variable types and sizes of saggers and separators, with one vessel per sagger, and the use of separators made from materials similar to the bodies. Glaze was scraped away from the point where it would touch a separator, to reduce the risks from sticking.[148]

[146] See Lao Fasheng *et al.* (1986), pp. 314–20; Zhang Fukang (1985), p. 31; Chen Liqiong (1986), p. 321.
[147] *Sung Hui Yao Chi Kao* ('Shih Huo'), p. 55:21.
[148] Li Dejin (1994), pp. 88–9.

IMPROVEMENTS

The side-stoked tubular dragon kiln was an extremely efficient design and even in its simplest form has seen continuous use in China for more than 3,000 years. Dragon kilns of this basic style still tended to be rather uneven in both atmosphere and temperature, however, and various local improvements were made to address these problems. Some early solutions occurred in Fukien province, particularly at Te-hua 德化 where the remains of an 'improved' dragon kiln of the late Southern Sung period can still be seen within Te-hua town.

The Chhü-tou-kung kiln 屈斗宮窯, now in central Te-hua, was more than 57 metres long with an average angle of 12–22°. Its width varied from 1.4 to 2.95 metres. This large and substantial structure seems to have been abandoned sometime after +1307, with many saggers and setters still in place.[149] Its particular feature was the division of the more usual continuous tunnel with partition-walls, to create seventeen separately stoked chambers. These chambers were about as wide as they were deep inside (*c.* 2.2 × 2.2 metres), with each chamber connected to the next by rows of slotted flues (five to eight separate holes per section), set at ground level. The passage of the kiln-gases was therefore converted from the usual roaring rise up the kiln's length, to a roller-coaster flame-path, through multiple successive chambers, with each chamber being side-stoked in turn. The floor of the kiln preserved the old dragon principle of a sloping bed of coarse quartz-grit, some ten centimetres thick, the so-called 'soft-bed' system.

The advanced design of the Chhü-tou-kung kiln forced the kiln gases to travel downwards against gravity for a large part of their journey through the kiln. This had the effect of further slowing the flame-speed, with consequent gains in firing efficiency. By placing each set of exit flues at ground level the kiln-builders ensured that the flames reached the floor of each chamber, before entering the next. This provided far more even temperature distribution, within the separate chambers, than the old sloping tunnel arrangement. By the time the Chhü-tou-kung kiln was built, kiln furniture consisted mainly of bungs (columns) of saggers, often with various styles of setters within. These features were designed to maximise setting-space. It seems likely that the overall kiln improvements were made both to improve evenness of firing and to allow close control of individual regions in the kiln. The porcelains fired at Chhü-tou-kung had rather short maturing-ranges, so kiln-losses from traditional dragon kilns may have been unacceptably high.

Archaeologists studying the Chhü-tou-kung kiln make a distinction between this design, which they call a 'chicken-cage' kiln, and a true Te-hua 'step kiln', which has a level floor to each chamber, and which appeared in the district in the Ming dynasty.[150]

[149] One sagger had a cyclical date on it, equivalent to either +1307 or +1367. The authors consider that as the articles found do not have Ming characteristics, the earlier date can be assumed, and that this was about when the kiln was abandoned, see Anon. (1979d), p. 57. Li Hui-Ping (1979), pp. 66–8, concurs.

[150] Ye Wencheng (1986), pp. 326–7. The term 'chicken-cage' probably refers to the rounded ends to the roofs of the separate chambers, which resemble open-weave cages used in Fukien province to transport chickens to market (NW observation +1995).

The angle of the floor is perhaps less important than the principle of partitioning the open tube of the old dragon design, and most other features of the Te-hua step kiln seem to have been anticipated in this advanced late Southern Sung design.

NORTH AND SOUTH: A COMPARISON

Thien Kung Khai Wu (+1637) states that in Chekiang province separate kilns were used for small and large articles, whereas in other regions small and large were fired together in one kiln. Archaeology does not wholly bear this out. The text describes a series of chambered kilns between 100 and 300 feet (*chhih* 尺) long, being constructed up hilly slopes. Several chambers were built together one above another up the slope, in order both to utilise well-drained ground and to allow heat to ascend. They were insulated with a three-inch layer of very fine soil[151] and had 'smoke windows' (i.e. stoke-holes) at five-foot intervals. They were filled with smaller pieces at the lower end, the largest cisterns being placed highest up. Fire was started in the lowest chamber, with two workers carefully monitoring the temperature. When the correct temperature was reached the firebox at the foot of the kiln was sealed, and a fire started in the second kiln and so on, till the top kiln was fired. Firing such large kilns was very expensive, so several potters shared both labour and expenses.[152]

This description post-dates the time that the Chhü-tou-kung kiln was in full operation, in the late +13th century. At the same time, coal-fired *man-thou* kilns, such as those excavated at Yao-chou, were firing celadon wares, blackwares and Tzhu-chou-style 磁州窯 stonewares. One way of regarding the Chhü-tou-kung kiln, in terms of flame-path and internal dimensions, is as a series of seventeen connected *man-thou* kilns built up a low slope. With regard to firing time the kiln probably took some 24 hours for the firebox and two to three hours for each of the succeeding seventeen chambers, giving a total of about 66 hours in all. This can be compared with the 100-hour firing described by Shui Jisheng for a typical northern coal-fired *man-thou* kiln producing smaller wares. It is therefore not impossible that the whole Chhü-tou-kung kiln took two-thirds the time to fire as a single medium-sized *man-thou* kiln, but produced seventeen times as much ware.[153]

As for its probable status, the archaeologists excavating the Te-hua site came to the following conclusion, which supports that found in historical texts like *Thien Kung Khai Wu*:[154]

We believe that the Qudougong [Chhü-tou-kung] kiln was neither a government-run kiln, nor a private kiln, but rather a folk kiln managed by a group of individuals. The products of the kiln were not the kind of articles for use in the imperial court, whereas the scale of

[151] In reality, insulation may have been much thicker.
[152] *Thien Kung Khai Wu*, ch. 7, pp. 5a–b; Sun & Sun (1966), pp. 145–6.
[153] These figures are typical for an early +20th-century Japanese *noborigama* kiln 登窯 of essentially similar design to the Chhü-tou-kung kiln. See Cort (1979), p. 401, Appendix B, note 1.
[154] Ye Wencheng (1986), pp. 326–7.

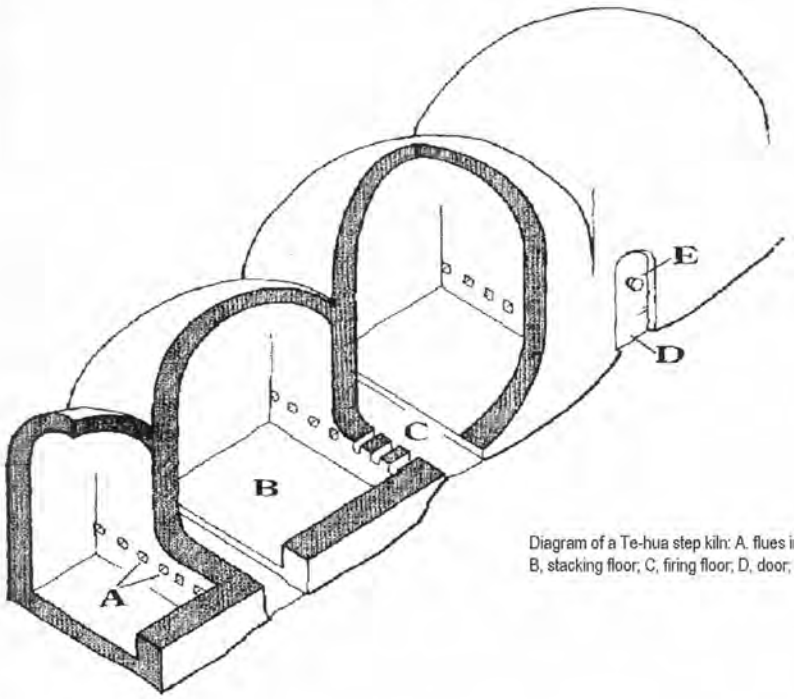


Diagram of a Te-hua step kiln: A. flues into adjacent uphill chamber; B, stacking floor; C, firing floor; D, door; E stoke hole.

Fig. 95 The step-kiln principle

production was too great to be handled by a single family. This suggests that the kiln was in the hands of an association of families, with manufacture being carried out in individual home workshops, and then carried to the kiln for firing.

The local clan at the time of the kiln's use was Cheng 鄭 and the authors believed that the kiln was co-operatively managed by an association of persons by the name of Chang 張 and Cheng, with many wares destined for export from the nearby port of Chhüan-chou 泉州.[155] In later centuries the Te-hua district produced both highly translucent ivory-coloured oxidised porcelains and reduction-fired blue-and-white wares. In general, the kilns designed for oxidation had deeper chambers with less extreme 'checking' of the flame-path, while in the reduction-fired kilns the flames were forced to follow a longer journey as they passed through the more vertical kiln-chambers, with the slower flame-speeds making reducing atmospheres easier to induce.

THE STEP KILN

The 'soft-bed' Chhü-tou-kung kiln, with its grit-strewn sloping kiln-bed, was replaced in Fukien province during the Ming dynasty. The new model was the step

[155] Anon. (1979d), pp. 58–9. The shared use of Te-hua kilns is also described on pp. 240–2 of this volume.



Fig. 96 Step kilns in use at Te-hua, +1936

kiln, a design that used solid and level stepped floors. A second change to the original design involved widening the separate chambers, while retaining their depth. By decreasing the numbers of these enlarged chambers to about seven it became possible to produce more compact kilns, but with capacities comparable to the longer designs. In some cases these wide chambers could measure eight metres across internally, which made side-stoking a more difficult process as the wood had to be thrown evenly into the narrow space left at the front of each chamber for the fuel to burn.

Many traditional Japanese *noborigama* kilns 登窯 seem direct descendants of this design, and the Japanese kilns were often stoked from both sides of the wide chambers simultaneously. The firemen co-ordinated their work by shouting '*hana*' (short), '*tsunake*' (medium) and '*donake*' (long), in order to spread the wood and generate an even wall of fire within the kiln-chamber.[156]

Step kilns are associated not only with Te-hua, but also with the distinctive export wares of south-eastern coastal China termed 'Swatow wares' by Western collectors. The source for these wares has long been debated, although few believed that they were actually made at Shan-thou 汕頭 (Swatow) on the north-east coast of

[156] Olsen (1973), p. 50. These calls must have been in local patois, and are not standard Japanese, according to Rupert Faulkner.

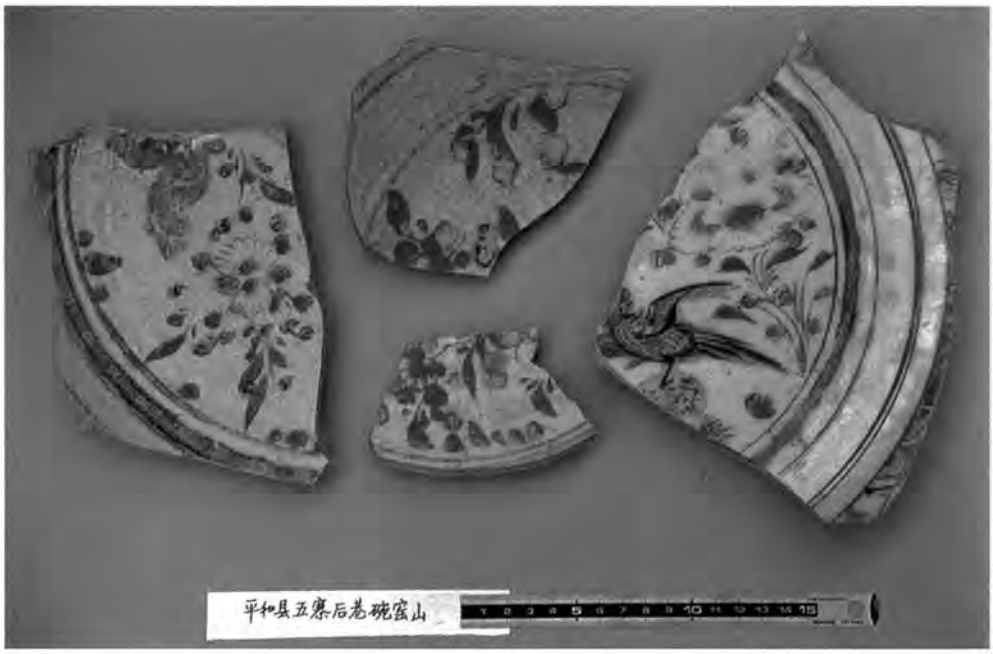


Fig. 97 Typical Swatow-style sherds with overglaze enamel decoration excavated at Phing-ho

Kuangtung province. Like the port of Imari in Japan that gave its name to a category of Japanese export porcelain, Shan-thou was one of the ports through which the wares could have been shipped, for the brief period of their manufacture *c.* +1575–1650. These dates have been confirmed by examples of the ware in datable Japanese contexts.

In +1994–5 Phing-ho 平和 in Chang-chou prefecture 漳州府 in southern Fukien province became the site of a joint-venture archaeological project between Fukien Provincial Museum, financed by Japanese sponsors, that revealed a plethora of kilns making Swatow-style wares. The kilns at Phing-ho are a short way inland, to the south-west of the port of Chang-chou 漳州.[157] Three localities were dug, and at least five late +16th- to early +17th-century step kilns were found. The locality of Nan-sheng 南勝 had more varieties of ceramic than the other two areas, comprising blue-and-white, overglaze enamel, slip decoration under brown glaze, engraved decoration under cobalt-blue or celadon glaze and a small number of low-fired lead glazes of green, yellow and/or aubergine, of *su san-tshai* 素三彩 type.[158]

[157] The kilns were visited by RK in April +2002.

[158] *Su san-tshai* 素三彩 refers to the technique whereby enamels are painted directly on to a fired ceramic body, without an intervening layer of glaze.



Fig. 98 Excavated late Ming dynasty step kiln at Phing-ho with three chambers, +2002

Saggers were employed, one per large vessel such as large dishes and basins, with multiple stacks per sagger for smaller dishes and bowls. Quartz-grit was used as a separator, giving rise to the characteristic 'sandy foot' of Swatow ware.[159] The number of chambers used for the Swatow kilns was quite limited. In most cases they employed one to three chambers, the number depending both on 'terrain and on the scale of the industry'.[160] Of course, a single-chambered step kiln is closer to a *man-thou* design in operation, albeit wood-fired and with a wider and shallower chamber than a northern kiln.

Single-chambered kilns were also used for lead-glazed wares at Nan-sheng and in September +1997 a specialised *su san-tshai* kiln locality was excavated in Tung-ku-yang東古洋. A small single-chambered kiln was found at this site, standing on a steep riverbank with workshop and clay preparation areas nearby. There must also have been a muffle kiln, though its discovery has not been reported. No wheels were used at Tung-ku-yang as all the items were moulded. The pottery compound had vertically integrated production, with everything from preparing clay to the second firing of low-temperature lead glazes occurring at one site.[161]

[159] Anon. (1997c), pp. 41, 62, pls. 23.1, 68.1, 68.5.
[160] Li Jian'an (1999), p. 518.
[161] Ho Chui-Mei (1997), pp. 1–3.

The very wide step kilns, typical of the Ming dynasty and of coastal provinces such as Fukien and Kuangtung were used occasionally inside Chiangsi province. Ruins of step kilns for firing blue-and-white wares have been found at Kuang-chhang 廣昌 in south-eastern Chiangsi, near to the provincial borders with Kuangtung and Fukien provinces. This large complex is also known as the 'Chung-ssu kilns' 中寺窯 after the local Chung-ssu river 中寺河. The site began porcelain production in the mid +14th century and the Chung-shih step kilns were firing blue-and-white wares until the mid +1960s.[162]

[162] Yao Chheng-Chhing & Yao Lien-Hung (1999), pp. 429–36.

KILNS AT CHING-TE-CHEN 景德鎮

Despite some impingement of the step-kiln design on Chiangsi province, the prime porcelain-producing site of Ching-te-chen seems hardly to have used the system. Nonetheless Ching-te-chen has yielded more kiln types than any other ceramic site in China, and these have included conventional dragon kilns, *man-thou* kilns, 'gourd-shaped' and 'egg-shaped' kilns. Numerous versions of small-scale enamel kilns have also been used at Ching-te-chen, together with medium-sized high-temperature kilns built to fire specific wares. Dragon, gourd-shaped and *man-thou* kilns were the earlier styles used, and have been described by Liu Hsin-Yüan 劉新園 in his +1989 report on Yung-Le and Hsüan-Te period excavations.[163]

DEVELOPMENT OF CHING-TE-CHEN KILNS

No structures of Five Dynasties kilns have been found so far at Ching-te-chen, although kiln furniture at Five Dynasties spoil heaps at Liu-chia-wu 劉家塢 and Lung-thou-shan 龍頭山 suggest dragon kiln use. The main discoveries there were thrown columns, designed to support stacks of bowls separated by brushed lines or dots of fine quartz-grit, of typical southern style, but saggers were absent. The lower levels at these Five Dynasties sites yielded only grey-bodied green-glazed wares, but higher levels contained a few white porcelains as well as stonewares, with the grey-bodied and white-bodied wares showed similar forms and making methods. Kilns were also missing from a dig at Hao-chu-ling 豪豬嶺, which yielded mainly *chhing-pai* wares. The earliest level 6 yielded sherds of Five Dynasties style but, in this case, saggers and setting-wads were found. Levels 1–5 produced *chhing-pai* wares 青白 typical of the middle and late Northern Sung periods.[164]

A kiln was unearthed at a Southern Sung to Yuan period site at Wu-ni-ling 烏泥嶺. This was a dragon kiln design, 2.9 metres wide, 13 metres long and built with a slope of 14.5°. The kiln fired coarser *chhing-pai* wares together with a smaller amount of blackwares. Some excavated setters showed use of the *fu-shao* (upside-down) firing method.

A longer and bigger kiln was found within the grounds of a printing-machine factory in the city. The dimensions of this kiln were 19.8 metres long with a slope of 12°. An unusual feature of the kiln was the narrowing of the structure's width from 4.56 metres at the front to 2.74 metres at the top. This kiln showed some features that were developed later into the Ching-te-chen gourd-shaped kiln. The kiln was

[163] Liu Hsin-Yüan (1989).
[164] See Liu Hsin-Yüan & Pai Khun (1980). Trans. Tichane (1983), pp. 394–416.

buttressed by kiln-furniture wasters of Southern Sung to early Yuan dynasty type, which helped to establish its date of operation.[165]

Thao Chi (*c.* +1214–1234) contained information relating to kiln design and operation. It noted that kiln size was strictly regulated and was recorded by officials. Taxation depended on the firing capacity of kilns, so size was important and unauthorised alteration to registered kilns resulted in imprisonment. Although kiln owners were independent skilled workers, not employed by others, they were required to rent their kilns to potters and were probably paid in kind. Bowls and plates were fired both upside-down and right-way up inside saggers, and the saggers were stacked carefully in the kiln prior to firing. The firing, which lasted one day and two nights, was carefully monitored by skilled masters (*yao-phai* 窯牌 and *huo-li* 火曆) who would work continuously in shifts, and consulted each other on the condition of the fire. The completion of firing was confirmed by examining the draw-trials (*huo-chao* 火照) that had been removed from the kilns using long hooks.[166]

Also in the Sung dynasty, a type of gourd-shaped kiln developed, deriving from and improving on the northern *man-thou* kiln.[167] A relatively small early or middle Ming example of this kiln type was found some 90 metres east of Wu-ni-ling, and this was of the developed gourd-shaped design peculiar to Ching-te-chen.[168] The kiln was 8.4 metres long and divided into two chambers, the first 3.7 metres wide and the second only 1.8 metres. The front chamber was shorter than the second, and the kiln floor sloped between 4 and 10°. The author of the excavation report speculates, from reading *Thien Kung Khai Wu*, that there may have been stoke-holes in both sides of the kiln, 'but they would be beyond recognition, as what was left were a few pieces of dilapidated wall'. The Ching-te-chen gourd-shaped kiln seems a hybrid design that incorporated elements of dragon, step and *man-thou* kiln principles. The slope seems shallow for its length, which may mean that a chimney was needed to assist its draught, although this is not mentioned in the report.

The full design and operation of a Ching-te-chen gourd-shaped kiln is still speculative as unlike bonfire, up-draught, dragon, *man-thou*, step and egg-shaped kilns, no working examples survive in China.

THE CHING-TE-CHEN 'EGG-SHAPED' KILN 雞蛋形窯

Described above are the main high-temperature kiln-types found associated with Ching-te-chen's earlier days. Whether each kiln-type was completely replaced by the next seems unlikely. The excavated sample is small and different kilns may have been used for firing different wares; different qualities of the same ware (such as blue-and-white) may have used different styles of kiln; and private country kilns may have continued with older designs as the newer kilns were developed or

[165] Liu Hsin-Yüan & Pai Khun (1980).
[166] *Thao Chi* in Pai Khun (1981), pp. 38–41.
[167] Hu Youzhi (1995), p. 287.
[168] Liu Hsin-Yüan (1980), pp. 50–60.

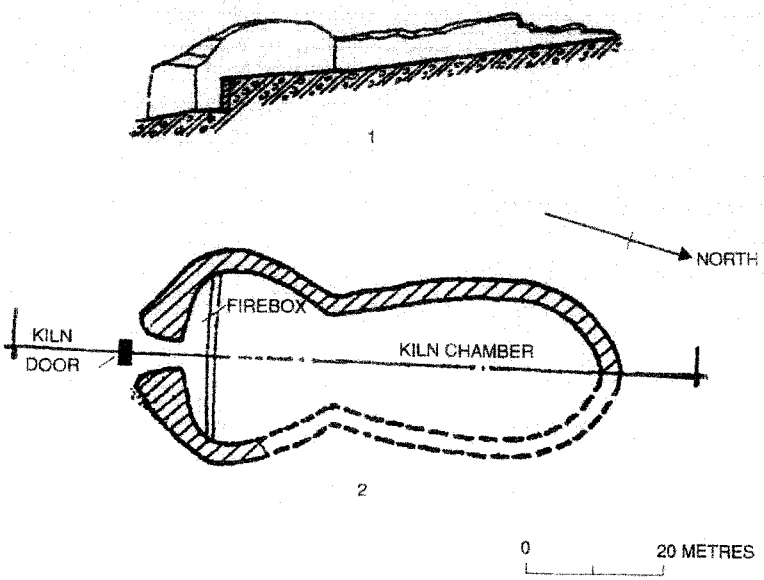


Fig. 99 Plan of an early or middle Ming dynasty gourd-shaped kiln

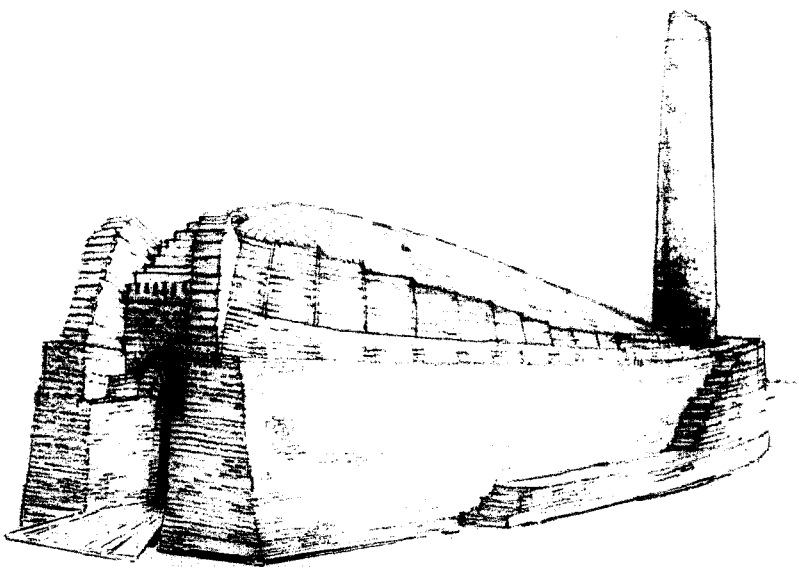


Fig. 100 Ching-te-chen egg-shaped kiln

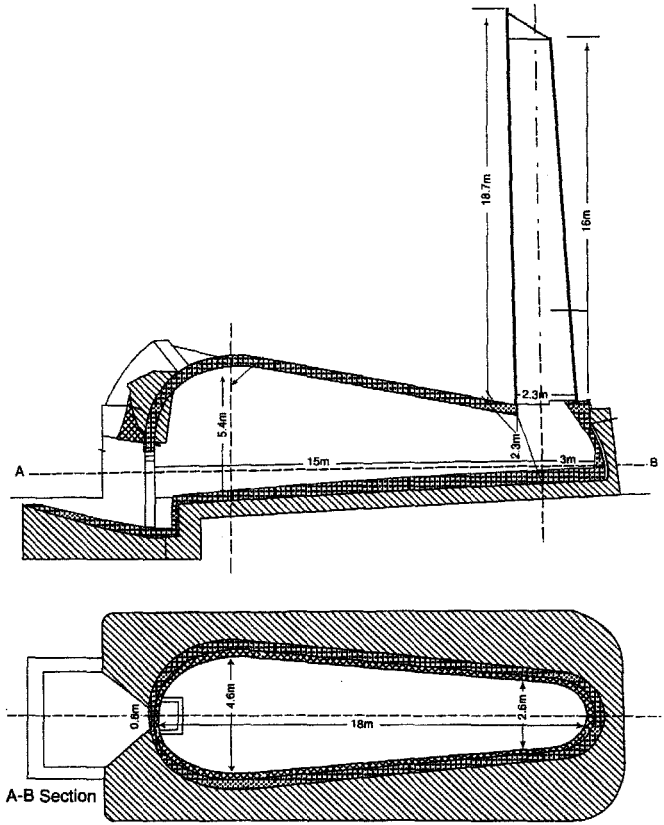


Fig. 101 Plans of a mid +20th-century Ching-te-chen egg-shaped kiln

adapted. Dragon kilns, for example, were still employed for firing rural stonewares some 60 kilometres south of Ching-te-chen as late as +1982.[169]

Kiln styles for firing porcelain at Ching-te-chen may not have finally settled down until the late Ming dynasty, when *chi-tan-hsing yao* or 'egg-shaped' kilns were constructed. This design was so successful that it saw continued use over several centuries. In the mid +1950s 70 examples of this large single-chambered wood-fired porcelain kiln were still in use, and were reported on by Russian specialists studying Ching-te-chen's porcelain production. Today only two egg-shaped kilns remain in use, mainly for firing reproduction wares. The latter half of the +20th century saw

[169] Visited by the authors in November of that year, at which time more than 400 dragon kilns were described as functional in Ching-te-chen.

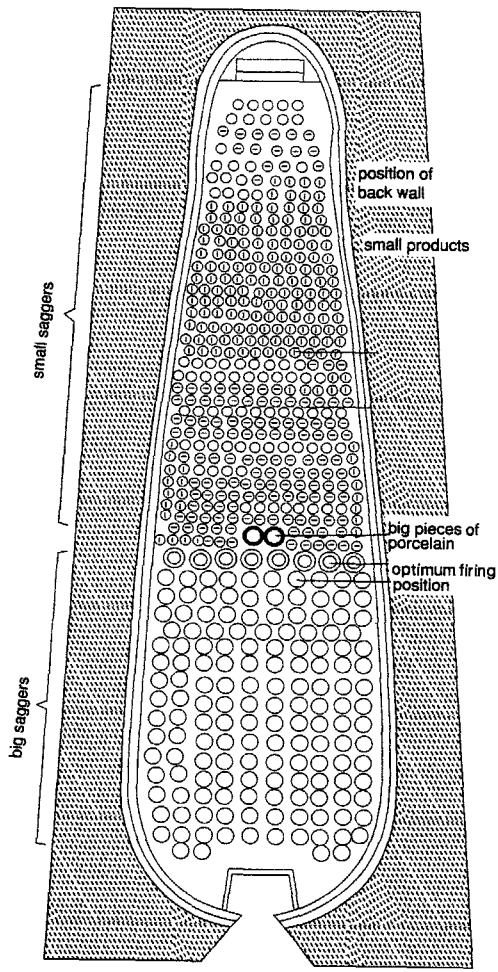


Fig. 102 Typical setting plan for sagger bungs in a Ching-te-chen egg-shaped kiln

the adoption of Western coal-, oil- and gas-fired kilns for Ching-te-chen's still-extensive porcelain manufacture.

The egg-shaped kiln continued the Ching-te-chen potters' preference for single-chamber designs, but took the principle to new levels of sophistication. The kilns were so complex that specialist firms were employed to construct them, such as that

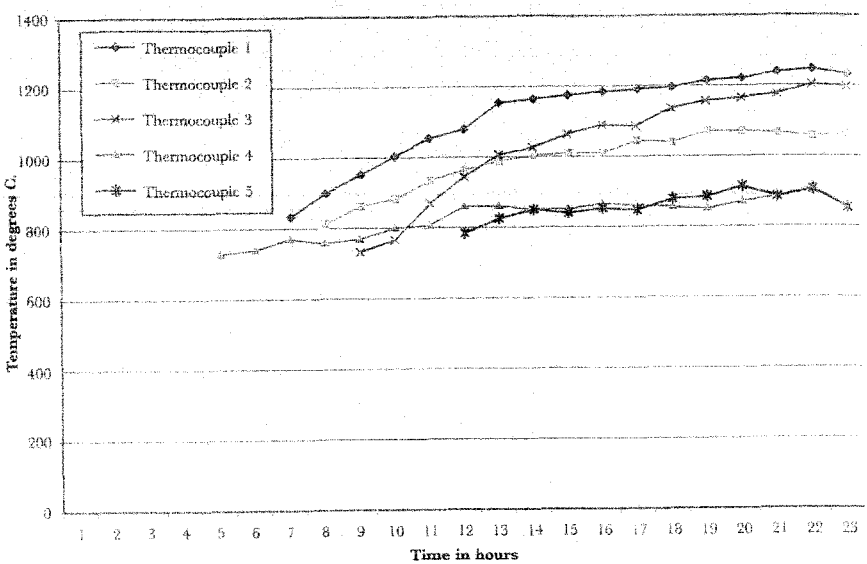


Chart 2 Temperature rises in various regions of a traditional Ching-te-chen egg-shaped kiln over the last seventeen hours of firing. These finishing rates are more comparable with those established for northern *man-thou* kilns, than southern dragon kilns, and suited the rather aluminous porcelains used at Ching-te-chen in the late Ming and early Ching dynasties

run by the famous Wei clan (see pp. 212–13). The shape of the kiln resembled half an egg lying on its side, with a wood-burning firebox set within its larger end, and a tall tapering chimney, of egg-shaped cross-section, rising from the roof of the smaller end. The chimneys tended to be as tall as the kilns were long inside, typically 10–15 metres, and were built with a spiral-laying technique and with mortar made from fusible clay. The 'streamlined' cross-section of the chimneys presented less resistance to prevailing winds, and the spiral bricklaying provided extra strength for the thin walls (*c.* 10 centimetres) and allowed the weight of the chimney to be taken directly on the vaulted roof of the kiln's far end.

In a similar way, the main shell of the egg-shaped kiln was relatively thin, with its bricks lain in a herring-bone manner that allowed easy repairs with minimal support. The floor of the kiln was bedded with quartz-grit and sloped slightly upwards (*c.* 4°). The main kiln wall was buttressed with loose bricks, which also supplied some insulation with its large volumes of dead air. The door of the kiln (always the weakest part of a kiln-structure) was particularly well buttressed and deeply recessed. Once the door was bricked-up after setting, a square stoke-hole was left half way up for feeding pine-logs, together with two holes higher in the kiln door

for admitting secondary air (i.e. the air that burned the smoke in the kiln).[170] Two remarkable aspects of the egg-shaped kiln were the speed of firing (24–36 hours from start to finish), and the great fall-off of heat that occurred from the firebox to the chimney-end (typically 1,320° to 1,000°C).[171] Nonetheless it was the acceptance and skilful exploitation of the steep temperature gradients that are inevitable in cross-draught kilns that made the egg-shaped kiln such a versatile design.

The kiln type perfectly complemented the manufacturing complexity that had been accumulating at Ching-te-chen over the centuries. This meant that the kiln could fire high-fired plain porcelains, intended for later enamelling; underglaze-blue and underglaze-red wares; celadon imitations; and a range of monochrome colours. All were fired simultaneously at high, middle and low temperatures. The Russian technologist G. L. Efremov describes how these kilns were set in +1956:[172]

> The first half of the kiln, nearer the entry, contains about 170 columns for firing at Seger cones 10–11; each column contains 30–40 fireclay saggers with porcelain coated with white glaze. In the second zone somewhat smaller coloured glazes are fired at Seger cones 8–9, and nearer the flues saggers are fired at Seger cones 1–5.[173]

Perhaps more remarkable still, the atmospheres in the egg-shaped kilns ranged from heavy reduction in the major part, through middle-fire (neutral atmosphere) some two-thirds of the way along, to true oxidation by the chimney. This meant that even oxidised low-temperature high-lead glazes, such as warm yellow monochrome glaze, could be fired in the same setting as well-reduced high-temperature porcelains decorated with underglaze cobalt-blue. Oxidation and low temperatures were assured at the chimney end by allowing some cold air to enter through holes in its roof.[174] Also, by avoiding lengthy soaking sessions at full heat, as practised with *man-thou* kilns, fuel consumption was modest. For example, 30–50 tonnes of wood seems typical for an egg-shaped kiln of 250 cubic metres capacity.[175]

[170] Short pine logs were used for the best wares, but one style of egg-shaped kiln burned branches: 'The branch kiln is smaller than [the] wood kiln, and the firing temperature of a branch kiln is lower than that of the log kiln, which can reach 1,350°C.' Hu Jing Qiong & Li Hao Ting (1997), p. 74.

[171] Karen Terpstra & Zhu Guihong write of one of the last egg-shaped kilns in China in Ching-te-chen, built in +1898 and now demolished: 'The total firing took from 18 to 24 hours, consumed 25,000–30,000 kilograms of wood, and fired 10–15 tonnes of porcelain work – excluding saggers.' Terpstra & Zhu (2001), p. 29. This 0.5:1 ware-to-fuel ratio compares very well with the 0.74:1 to 2.91:1 ware-to-fuel ratios established for Staffordshire coal-burning kilns and quoted in Singer & Singer (1963), p. 914, table 212, particularly when the higher calorific value of coal (almost 50% more than wood, weight for weight) is taken into account. A typical mid +20th-century Staffordshire coal-burning kiln firing bone china biscuit to 1,250°C took 55 hours to reach temperature. Singer & Singer (1963), p. 879, table 200.

[172] Efremov (1956), p. 492.

[173] Cones are thin flat-sided cones of compressed ceramic material about two centimetres long, with various compositions each designed to soften and bend after a certain amount of heat work has been carried out. They are set amongst the wares and watched by the firemen through spyholes in the kiln wall or door, for characteristic bending or arching over when maturation is reached. As maturing temperatures rise so do the cone numbers, with Cone 34 being made from pure kaolin, with a softening temperature in the region of 1,700°C. See Seger (1902b), pp. 224–49.

[174] Vogt (1900), p. 582. Tichane (1983), p. 269, translates: 'It may be that turquoise, which of all the glazes in the high fire needs an oxidizing atmosphere in order to develop a good color, should be placed near the chimney, for this atmosphere can easily be obtained there by the entrance of air skilfully managed with the help of the last holes placed near the top of the arch.'

[175] Hu Youzhi (1995), p. 286.

In the +18th century the large high-temperature kilns were described as long and round, resembling a large urn (*weng* 甕) on its side. This is the same shape as the other description of an egg-shaped kiln. The largest kilns were 18 metres long, 4.6 metres wide and 6 metres high. The whole kiln area was roofed over with tiles like a house, and behind this kiln-shed rose a tall chimney some twenty feet (*chhih* 尺) high.[176] Of all tasks at Ching-te-chen, work at these kilns was among the most exhausting. A small staff, usually about four or five foremen, two kiln inspectors and two assistants, had already laboured hard the day before the slow firing was started when they supervised the loading of the kiln. During the period of intense stoking there was no rest or sleep for a day and a night. Constant inspection of the fuel, the state of the fire and the saggers was necessary, taxing the energy and ability of the workers to the limit.[177]

HISTORICAL DESCRIPTIONS OF THE SETTING AND FIRING OF THE EGG-SHAPED KILN

Chiangsi Sheng Ta Chih (Great Gazetteer of Chiangsi Province, +1597), *Thien Kung Khai Wu* (The Exploitation of the Works of Nature, +1637), *Thao Shuo* (Description of Ceramics, +1774) and *Ching-te-chen Thao Lu* (An Account of Ceramic Production at Ching-te-chen, +1815) between them record a lot of information about the management of kilns.[178] The arrangement of various wares within such large cross-draught kilns was crucial. Saggers filled with porcelain were loaded by workers and placed in lines with small gaps or fire channels between them.[179] Wares were placed in the kiln according to firing needs, for texts confirm that the fiercest heat was at the front, with medium heat in the centre and gentle heat at the back. Thus only very coarse pieces were put in the first two rows of saggers inside the entrance, to act as a screen against the roaring flames. Sometimes private kilns put empty saggers at the front to screen the fire, while in the Ming dynasty official kilns always kept three front rows of saggers entirely empty. The next six to seven rows of saggers were filled with rough wares; the following three rows with mixed ware; the best ware was placed in the next four rows; and rough wares again in the back three to four rows. Differences in the amount of care taken in stacking the kilns could be judged by the fact that official and private kilns use the same amount of wood, but the latter produced twice the number of pots in a single firing. Private kilns also fired mixed loads of wares.

After the kiln was completely loaded with saggers, a fire was lit and the door bricked up, leaving only a square hole through which small fir logs were ceaselessly

[176] *Thao Shuo*, pp. 9b–10a; Hu Youzhi (1995), p. 286.

[177] *Chiangsi Sheng Ta Chih*, ch. 7, pp. 24a–b.

[178] *Chiangsi Sheng Ta Chih*, ch. 7, pp. 17a–b; *Thien Kung Khai Wu*, ch. 7, pp. 8a–b; Sun & Sun (1966), p. 154; Nos.15 and 16 of Thang Ying's description of pottery-making, in *Thao Shuo*, ch. 1, pp. 9b–10b; *Ching-te-chen Thao Lu*, ch. 1, pp. 5b–6a; ch. 4, pp. 4b–5a, 6a.

[179] The flame channels were carefully measured and marked out, using two to four pieces of 4 × 6 centimetre sagger fragments stuck down with liquid clay. Some channels were straight, and some deliberately curved to allow some resistance to flame heat. Hu Youzhi (1995), p. 288.

fed. Towards the top of the kiln there were twelve round stoke-holes. Seven days and nights of slow firing were used to remove all moisture from the raw porcelain bodies (*liu-huo* 溜火), building up to two days and nights of intense firing (*chin-huo* 緊火) when the saggers turned from red heat to white heat. The intense stage of firing took 48 hours, of which the first 24 used heat from wood stoked through the kiln door that rose from the bottom to the top of the kiln. During the last 24 hours wood was inserted through the upper stoke-holes to let heat travel from the top downwards. At this point, the porcelains were described as being 'soft like cotton wool'.[180] To monitor firing, testers of clay with holes in the middle were lowered into the kiln on hooks and stoking was stopped when the draw-trials were judged sufficiently fired. Management of firing – keeping the fire at the right temperature and the heat circulating properly – was done entirely by eye through observation holes, by the 'fire eyes' (*huo-yen* 火眼). At the end of the firing, oxidation cleared the atmosphere in the kiln so the supervisor could see straight through from front to back. The fire was quenched, the doors were sealed for ten days, and the kilns opened when they had cooled.

Success or failure could be judged immediately the kiln was opened. At that point some saggers were still red hot, and it was a while before the workers could enter the chamber with their hands protected by cloth folded over more than ten times and soaked in cold water, and their heads, shoulders and backs protected by wet cloths. Once the kiln had been drawn it was set again quickly, both to utilise the heat for initial drying, and also to reduce the amount of fuel needed to heat the structure. This also helped to prevent breakage and cracks from firing later on.

Labourers who loaded the saggers and set the porcelain kilns lived in separate lodgings and worked under pre-agreed terms. Specific regions in and around Ching-te-chen supplied workers in different periods. In the +18th century men from Tu-chhang 都昌 and Pho-yang 鄱陽 in Fu-liang 浮梁 worked in two separate groups filling pine-faggot and brushwood kilns, with pine faggots being reserved for the finest wares, and brushwood for everyday pottery.[181] Typical kilns required about 120 loads of wood (*kung* 擐) for a firing,[182] and an extra ten *kung* when it was cloudy and raining.[183] The huge quantities of fuel required were delivered by boat. The activity was unionised (see p. 213) and skilled, for the wood needed to be dried right through and there was close inspection and monitoring of quality. Wood was used exclusively until the post-Chhing period; experiments with coal firing in the late Chhing dynasty were unsuccessful, for the sulphurous fumes stained the porcelain and the kilns were not modified to use the fuel.[184]

[180] This is a reference to pryoplasticity, the phenomenon that can render porcelain at high temperature as soft as when it was on the potter's wheel.
[181] *Ching-te-chen Thao Lu*, ch. 4, pp. 4b–5a.
[182] About six tonnes, see Sayer (1951), p. 46. Hu Youzhi (1995), p. 286, says that 30–50 tonnes of wood were used for every firing of the largest kilns, whose volume was about 250 cubic metres.
[183] *Chiangsi Sheng Ta Chih*, ch. 7, p. 17b.
[184] *Chiangsi Sheng Ta Chih*, ch. 7, pp. 24b–25a; *Anon.* (1959a), pp. 285–6.

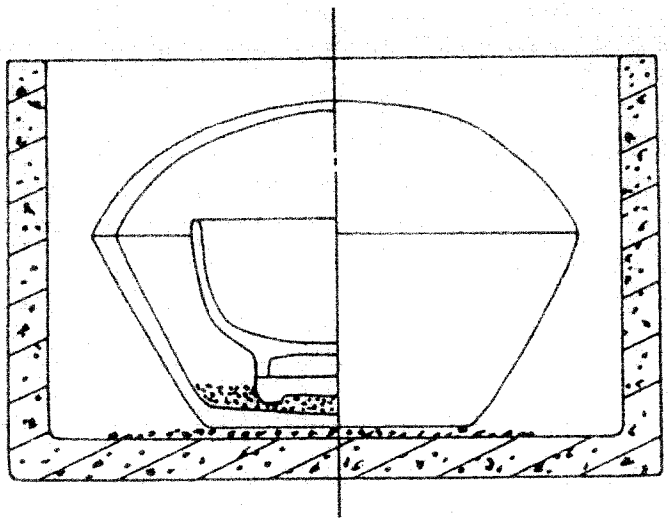


Fig. 103 A Hsüan-te period imperial bowl packed for firing, standing on a disc-shaped support inside a covered box, then inside a sagger for double protection

It was also a feature of some firings that water was sprayed on the front of the kiln at nearly full temperature, while wet wood was being introduced to the firebox. The resulting combination of black smoke and steam probably encouraged some hydrogen reduction within the ware-chamber, improving reduction and evening the kiln's temperature to some extent. This smoky stage took place one to two hours before the end of the firing, so excess carbon could be burned away before the firing ceased.[185]

Textual evidence supplemented by excavation has elucidated the manner in which the saggers were filled. In private factories, the wares were tightly stacked and supported on clay discs, the empty space at the bottom of each sagger being filled with sand. Single saggers were used for large items, while small pieces were stacked up to ten or more per sagger. Good saggers could be used for upwards of ten firings, whereas poor ones disintegrated after one or two.[186] At the imperial factory, the processes were more specialised. By the Yung-Le and Hsüan-Te reign periods, funnel-shaped saggers and disc-shaped supports made of sagger clay, such as those common in the Sung and Yuan dynasties, were no longer employed. Instead, saggers were flat-bottomed, with white porcelain supports that were trimmed on the

[185] Terpstra & Zhu (2001), p. 28.
[186] *Thien kung khai Wu*, ch. 7, p. 8a; Sun & Sun (1966), p. 154.

wheel. Such supports achieved a uniform rate of expansion and contraction between the support and the vessel, as the temperature in the kiln rose and fell. They also reduced contact points to a minimum, so both glaze and marks on the base of pieces were unblemished. Special covered boxes made of white china clay were also found that were unlike anything found at other kiln sites. They were designed to encase vessels in an upright position in firing.

They were loaded by spreading a layer of kaolin mixed with ground husk on the base of the box as a separator, placing disc-shaped supports on this mixture and bowls or dishes on the supports, and then replacing the lid. The covered boxes were themselves put in saggers, on the base of which was kaolin and ground husk. This double protection for very fine pieces prevented kiln dirt, caused by the release of some of the iron contained in the sagger material under reduction conditions, from falling on to fired articles. The covered boxes were expensive, for they could only be used once; the very act of firing vitrified the porcelain walls of the box, so that they became non-porous and could not thereafter permit circulation of air. They were therefore reserved for the best imperial wares only.[187]

The firing process as described in textual sources is confirmed by modern commentators when they say:[188]

> When the saggers are totally white and the atmosphere is clear, the 'fire eye' spits saliva into the observing hole. If the saliva vaporizes into a white vapor and rises up into the chimney immediately it is time to stop firing. Otherwise, the firing process continues.

When the firing was judged complete, the fire was quenched, the doors were sealed for ten days, and the kilns opened when they had cooled.[189]

'Dragon Cistern' Kilns, 'Green Kilns' and Enamel Kilns

In the imperial factory there were also kilns devoted specifically to the firing of large 'dragon cisterns'. In the Ming dynasty, these were 6 foot (*chhih* 尺) wide in front, 6 feet 5 inches (*tshun* 寸) wide at the rear, 6 foot deep, and had a domed roof, which suggests a *man-thou* design. They baked one piece at a time of the largest or second-largest cisterns, while for the third-largest, shelves were used and two were fired together. The kiln was heated slowly for seven days and nights, with the flames 'just flickering low like trickling water' to completely dry out the thick bodies of the cisterns. Then fierce firing took place for two days and nights, and just like the larger kilns the fire was quenched, the doors sealed, and reopened after ten days. Each kiln

[187] Liu Hsin-Yüan (1989), pp. 48–50, 77–9.
[188] Hu Jing Qiong & Li Hao Ting (1997), p. 82.
[189] *Thao Shuo*, ch. 1, says that the kiln was left for only a day and a night before being opened, the whole process taking three days and the kiln being opened early on the fourth day. This timing accords with modern firing. Hu Youzhi (1995), p. 289, points out that the firing process was determined by the distribution of flame channels within the kiln, the quantity and sort of products being made, and prevailing weather conditions.



Fig. 104 Remains of small muffle kilns in the imperial factory

devoured about 130 loads of wood, but if it was cloudy or rainy could use more.[190]

The imperial factory also housed 'green kilns' (*chhing-yao* 青窯), which were slightly smaller than the cistern kilns and were used for loads of smaller pieces. A typical setting might be over 200 middle-sized plates and dishes; or 156 slightly bigger ones; or 24 large bowls, 30 bowls and 16–17 large jars; or 500–600 small wine bowls. They were slow-fired for two days, intensely heated for a day and a night, and opened on the fifth day after the kiln had cooled. They used 60 loads of wood if firing larger vessels or when the weather was wet.[191]

After pre-firing in the high-temperature kilns, porcelain that was decorated with overglaze colours had to be fired a second time in a muffle kiln. Charcoal was the only fuel employed to fire muffle kilns, with the clean glowing combustion of the fuel suiting these low-firing oxidised lead glazes.[192] Two types of enamel kiln were used, a bright (open) type and a dimmed (muffle) kiln. The bright kiln was used for smaller vessels, and had an outward-opening door. The kiln was lit all round the sides, and items were placed on an iron wheel attached to an iron fork, which was used to lift and lower them into the kiln. The iron wheel was turned using an iron hook so that firing was uniform. The muffle kiln was used for larger pieces and was three feet high and two and a half feet across, with a double wall pierced at the

[190] *Chiangsi Sheng Ta Chih*, ch. 7, p. 18a; *Ching-te-chen Thao Lu*, ch. 5, p. 5b.
[191] *Chiangsi Sheng Ta Chih*, ch. 7, p. 18a.
[192] *Anon.* (1959a), p. 287.

bottom with draught holes. The charcoal was lit inside, and the porcelain loaded into the hot kiln by muffle-kiln operators, who protected themselves from the heat with hand-held circular shields. The kiln was completely sealed with thick yellow clay, and was reopened after a day and a night.[193]

The remains of a very small muffle kiln was discovered in the Hsüan-Te stratum at the imperial kiln site and, although its main chamber was damaged by later construction, the kiln door, kiln bed, rear wall and six smoke ducts were discernible.

In +1988 five more relatively small, horseshoe-shaped, semi-muffle kilns were discovered in the front court of the factory.[194]

From the beginning of the Chhien-Lung reign period the number of small workshops with muffle-kilns producing overglaze decorated wares increased. They were popularly known as 'red shops' (*hung-tien* 紅店), and their owners no longer used the methods of 'open' and 'closed' kilns; those terms for the stoves passed out of use. The practice was to construct simple, round brick structures as needed, and to seal them on top after the fire was lit.[195]

Sagger Kilns

A separate but closely related industry was the making and firing of the saggers, an operation controlled by its own guild. Sagger-makers sold both fired and unfired saggers to kilns, including the imperial factory.[196] Saggers were first baked blind, i.e. biscuit-fired without ware in them. Only then were they filled with porcelain, and this was called 'gilding the sagger'. Sagger clay came from Li-chhun-tshun 里淳村 north-east of the town, or from Ma-an-shan 馬鞍山, Kuan-chuang 官莊 and other places in the district, and was of three different colours: black, red and white. Clay was mixed with blackish-yellow sand from Pao-shih-shan 寶石山, the resulting paste being formed on the wheel in the same way as porcelain vessels. Saggers were, however, more roughly finished, for after partial drying they were simply pared with a knife.[197] Other methods of making saggers included coiling, coiling and throwing, hand-forming and forming in tube-shaped moulds.

Kilns for firing saggers were similar to the 'green kilns', though they varied in size and fuel requirements. An average kiln could fire 70–80 large and small saggers, using 55 loads of wood. Even damaged saggers could be sold. Separate kilns were used to fire huge saggers for large dragon cisterns, and they burnt considerable quantities of wood (60 loads each). Kilns were slow-fired for three days and nights, intense-fired for a day and a night, and sealed for three days after quenching the

[193] Thang Ying's illustrations to pottery-making no. 18, in *Thao Shuo*, ch. 1, pp. 11a–b. See also *Ching-te-chen Thao Lu*, ch. 1, pp. 6a–b.

[194] Their average length was ten metres. Feng Hsien-Ming *et al.* (1982), p. 361; Liu Hsin-Yüan (1989), pp. 48–50, 77–9.

[195] *Ching-te-chen Thao Lu*, ch. 4, p. 3b.

[196] *Anon.* (1959a), p. 296.

[197] Thang Ying's illustrations to pottery-making no. 4, in *Thao Shuo*, ch. 1, pp. 4a–b; *Ching-te-chen Thao Lu*, ch. 1, pp. 3a–b.

fire. Sagger kilns required even higher temperatures than those for porcelain wares, but atmospheric control was not so crucial.[198]

SUMMARY OF PART 3: 'KILNS'

Perhaps the most important and defining difference between ceramics and most applied arts lies in the way that clay is entirely transformed in its nature and in its appearance at the very last stage of manufacture, by firing. This is an irreversible process that creates a new substance that is hard, permanent, and capable of bearing a fused glassy coating. This transformation is especially dramatic in the case of raw-glazed porcelains. The wares are placed in the kiln as fragile shells of raw clay, covered with dusty coats of white glaze-powder. They emerge from the kiln some 40% smaller by volume as intensely hard, shiny and translucent white vessels with an appearance somewhere between ceramic and glass.[199] The firing of translucent porcelain is the ultimate transformation in historical ceramics, and is as far as one can take a ceramic material before it eventually collapses and melts.

As Part 3 shows, China's high-temperature kilns developed in two very different ways, above and below the Nan-shan–Chhin-ling divide. The *man-thou* kiln design dominated northern ceramic production, while dragon kilns spread everywhere in the south. Four factors in particular seem to have decided this separate development:

- the different natures of northern and southern Neolithic kilns
- the general adoption of coal firing in north China in the +10th to +11th centuries
- the spectacular success of the southern dragon kiln
- the rather different natures of northern and southern clays.

Man-thou kilns saw (and still see) extensive use in south China for firing grey bricks, but the dragon kiln is virtually absent from the northern provinces. There are transitional areas, however. For example, mixed use of both *man-thou* and dragon kiln designs occurred in Szechuan province, apparently due to northern and southern influences respectively. Ching-te-chen potters too used *man-thou* kilns for firing some porcelains in the early Ming dynasty, and apparently in the imperial factory in the Ming and Chhing dynasties, though they used wood rather than coal as fuel. In terms of efficiency the side-stoked dragon kiln of south China proved the superior design, and much of the success of the huge ceramic industries that developed in the south depended on the use and gradual refinement of this simple structure, which reached its most advanced condition in the step kilns of Fukien and Kuangtung provinces. The last great historical kiln development occurred at Ching-te-chen in the late Ming dynasty, when the 'egg-shaped' kiln was perfected. This is often regarded as the definitive Ching-te-chen kiln type and, once established, the design saw continuous use into modern times.

[198] *Chiangsi Sheng Ta Chih*, ch. 7, p. 18b; Liu Hsin-Yüan (1989), pp. 49, 78–9.

[199] Volumetric shrinkage is three times linear shrinkage, which tends to be some 10–15% from plastic to fired in most Chinese porcelains.

PART 4: MANUFACTURING METHODS AND SEQUENCES

NEOLITHIC TECHNIQUES

MODELLING CLAY IN THE PALAEOLITHIC PERIOD

It is not hard to imagine the fascination that various clays and clay-like materials must have exerted in the Palaeolithic era, as early man prised clay from river-banks, beaches, cliffs and stream beds, discovered that damp earth could be moulded, or that clear footprints were left in mud. Small, solid unfired figurines may well have been the first clay objects made by man,[1] although initial attempts at combining this material with fire seem to have been concerned more with the excitement of seeing the figurines explode, rather than with attempts to give them permanent form.[2]

While the making of clay figurines (whether fired or unfired) may pre-date the making of ceramic vessels in many cultures, evidence for this particular stage is still lacking for China. The earliest properly shaped and fired ceramic known at present from China is a small, reconstructed jar, some eighteen centimetres in height, unearthed from the Hsien-jen-tung 仙人洞 in Chiangsi province in +1962, and dated to −8,870 ± 240.[3] The chronology proposed for this find from Hsien-jen-tung can be compared with the Fukui Cave 福井洞穴, Japan, where potsherds were discovered in stratum 2 that dated to −10,700 ± 500.[4] Africa has pottery dated to *c.* −7,370 ± 110 in the Sudan;[5] and ceramics from the upper Tigris basin date back to *c.* −6,000.[6] Recent finds from Amazonia show that pottery-making in the New World may date back to at least −3000.[7] On this evidence China is certainly an early, although not the earliest, maker of ceramic vessels. This outline chronology must still be regarded as provisional, however, as it is based on limited excavation.

[1] 'Although the earliest invention of ceramics – the first thoroughly artificial objects – can be credited to Gravettian figurine makers at Dolni Vestonice around 26,000 b.p., the use of pottery vessels is so far not known to have occurred until after the global changes that accompanied the advent of the Holocene.' Hoopes & Barnett (1995), p. 2.

[2] Vandiver *et al.* (1989), p. 1007, note: 'We must entertain the possibility that these workers were not trying to produce durable ceramic images and the earliest use of ceramics might have been for their special and unique fire-related properties rather than for a function based on their visual appearances.'

[3] The accurate reconstruction of ancient vessels from very small sherds has been a subject of discussion among archaeologists, see Part 1 p. 2 and Hill (1995).

[4] 'Pottery is radiocarbon dated to about 12,700 b.p. in a good cultural and stratigraphic context at Fukui Cave, not far from Nagasaki City 長崎市 on Japan's southern island of Kyushu. So far it remains the earliest dated pottery in the world.' Aikins (1995), p. 11, referring to pottery vessels.

[5] See Close (1995), pp. 23–37, for a detailed review of dates and contexts for the earliest ceramics so far discovered in Africa.

[6] Moore (1995), p. 40.

[7] Roosevelt (1995), p. 115.

In terms of material, the jar from Hsien-jen-tung is made from gritty earthenware clay, identical with the local earth in both analysis and texture.[8] Its outside surface is covered with fine parallel vertical marks that may have been a by-product of making, although they also provide some ornament to the form.[9] Its fine rim is some five millimetres tall and slightly thickened. Smoothness and strength from thickening are often added to rims of pots during manufacture as this helps discourage the fine vertical cracks caused by differential shrinkages in drying. Rims tend also to be the weakest parts of fired ceramic vessels in use, and benefit from some strengthening at the production stage.

MAKING THE VESSEL FROM HSIEN-JEN-TUNG

Assessing the sequences that have been involved in the construction of ancient hand-built ceramics is a well-known trap for the unwary as different manufacturing regimes can give identical fired results. Modern anthropological studies have shown how even neighbouring villages may use different methods to produce similar vessels and that, within a single workshop, the same vessel-shapes may even be made by distinctly different techniques.[10] Constructive possibilities tend to multiply with the scale of the objects made. Round handfuls of clay, the size of a small orange, are easily pinched, and then beaten, into vessel-shapes up to about twenty centimetres in height and width, without the need to add more clay. This is the point at which making methods tend to diverge. There is also the fact that techniques observed at traditional workshops by fieldworkers must still be treated with care, in case they are relatively recent introductions or innovations. On this issue Cort and Lefferts go so far as to say that:[11]

> Given the current state of ceramics material analysis, we are convinced that it is not possible to extrapolate from contemporary production into the past with any degree of certainty.

Cautionary tales about assuming how much is 'traditional' at apparently 'unreconstructed' rural workshops are also well described by Brian Moeran in a paper written in +1987.[12]

While bearing these important reservations in mind, traditional manufacturing techniques in rural societies can still provide good starting-points for the consideration of ancient pottery practice. For example, the field investigations of traditional pottery-making in Yunnan, already mentioned in connection with kilns, also dealt

[8] Fang Fubao (1992), p. 542, writes: 'the raw materials were selected from the locality. The clay texture was loose and rough. The clay was red with uneven grains of quartz.' The material has since been shown by analysis to be another example of a southern surface clay that was potentially a stoneware material, although fired at this time only to earthenware temperatures (*c.* 740–840°C).

[9] This is by no means exceptional: the earliest ceramic vessels from most cultures tend to bear impressed or incised decoration.

[10] Pers. comm. to NW by the Singapore potter Peter M. Lau, who described south Malaysian methods for making visually identical stoneware dragon jars, wholly by coiling or wholly by throwing, within the same traditional workshops.

[11] Cort & Lefferts (2000), p. 50.

[12] Moeran (1987), pp. 27–33.

with hand-building methods, the simplest of which might relate to the vessel from Hsien-jen-tung.

'STONE AGE' STYLES OF POTTERY-MAKING IN PRESENT-DAY YUNNAN

For a period of two months in +1977, a team of ceramic scientists and art historians studied traditional manufacturing methods and sequences for unglazed and glazed earthenwares at stockaded villages in the counties of Ching-hung 景洪, Meng-hai 勐海 and Hsi-meng 西盟 in Yunnan province.[13] The simplest technique used in this area (by the Wa nationality at Kho-lai stockaded village) was described by the investigators:[14]

Hand-modelling with a soft pad . . . The soft pad is made of a shallow bamboo basket stuffed with grass and covered with hemp, on which the clay is roughly fashioned by hand in the form of a vessel, then with the help of auxiliary tools mentioned above the shape of the roughly fashioned vessel is further improved and patterns are impressed on the outer surface.

The 'auxiliary tools' illustrated in the report are a pebble, patterned wooden paddles and a piece of cloth or leather, all classic instruments for forming and finishing hand-built pots the world over. Perhaps the most obvious features of vessels made in this way are the repeating patterns on their surfaces, picked up from the textured paddles as they beat the roughly formed vessels into shape, and consolidate and thin their walls. Deft use of wet leather on the pots' rims can thicken and finish their tops in a neat and decisive manner. A subjective impression is that the jar from Hsien-jen-tung was made from single piece of clay that had been roughly pinched to shape, and then beaten into its finished form by paddle and anvil methods. The rim was probably smoothed with thin leather (or perhaps a wet leaf) in order to complete the object.

Hsien-jen-tung dates from the dawn of China's late Palaeolithic to early Neolithic, *c.* −9,000 to −4,000, and is located in southern China. Slightly later in China's ceramic history are some fine northern wares, such as those from the Phei-li-kang 裴李岡 site in Honan province. These plain but finely made vessels date from the period −6,000 to −5,700. Their forms are based on spheres, cylinders and hemispheres, and show details such as three short conical legs and small well-formed handles, which give something of a Bauhaus spirit to Phei-li-kang Neolithic ceramic design. A similar sense of abstract geometry imbues the forms of early Neolithic ceramics from the Kuan-chung 関中 region, particularly those from the lower layers of the site at Pei-shou-ling 北首嶺 in Shensi province. However these wares, found some 26 kilometres north-east from Lin-thung county 臨潼縣, differ from the Phei-li-kang vessels in their subtle use of fine texture, either beaten or impressed, and often employed to contrast burnished areas on the same vessels.

[13] Cheng Zhuhai *et al.* (1986), pp. 27–34.
[14] *Ibid.*, p. 29.

Some archaeologists posit that these Phei-li-kang and Pai-chia wares, from the early Neolithic:[15]

> not only antedate the emergence of agriculture in ancient China for more than 1,000 years but also reveal the indigenous root of the Yang-shao culture.

The Phei-li-kang vessels show no signs of beating, but their surfaces appear to have been scraped or burnished smooth. The construction of Phei-li-kang ceramics has been described by Shelagh Vainker:[16]

> The earliest vessels appear to have been constructed from pads of clay usually no greater than about 6 by 4 cm, pressed together to build up a pot by creating a patchwork in vessel form. The technique appears to have been used in what is loosely called the Peiligang [Phei-li-kang] culture (*c.* –6500 to –5000) of central northern China.

As with the working of hardstones in the Chinese Neolithic, the means employed to achieve pure form have been disguised by careful finishing, so rather subtle techniques of investigation are needed to establish making methods that may have been used.

XERORADIOGRAPHY

Perhaps the most useful approach to revealing original manufacturing methods and sequences for ceramics has come from the application of xeroradiography, both to sherds and whole vessels. Xeroradiography is an X-ray process that uses a selenium-coated aluminium plate rather than a sheet of photographic film. A positive electrostatic charge (1000–1600 volts) is placed on the plate's surface before exposure to the X-rays. Partial depletion of this charge corresponds to the X-ray image, which can be 'developed' by spraying the plate with charged pigment particles, which are usually blue. This image can then be printed directly on to paper or plastic.[17] The method shows less scatter (blurriness) than an ordinary X-ray, together with good edge enhancement.[18] It can clearly show variations in the clay fabric, and can reveal signs of systematic beating and coiling, even when all visible traces of these methods have been obliterated in finishing.[19]

Xeroradiography has been applied by Pamela Vandiver to jars of the Pan-shan 半山 type from Kansu province, made during the -4^{th} millennium, in order to compare and contrast their construction with Near Eastern vessels of the -6^{th} millennium

[15] Anon. (1993), Institute of Archaeology, Chinese Academy of Social Sciences, pp. 5–11.

[16] Vainker in Rawson (1992), p. 220, see also p. 253 for a discussion of sources.

[17] Use of this method for the study of archaeological artefacts was first suggested by Heinemann (1976), pp. 106–11. See p. 106 and p. 110 for a more detailed account of the technique.

[18] Alexander & Johnston (1982), p. 147.

[19] All plastic clays contain considerable amounts of trapped air. These are driven out to some extent by the pressures used in making, at the same time as the clay's platy particles are forced into better alignment, giving areas that appear darker by xeroradiography. However xeroradiography does not record density as such: 'The image thus represents not values of density in the imaged object, but gradients in the line-integrated density (which causes gradients in the X-ray intensity at the imaging plate).' Vandiver *et al.* (1991), pp. 187–8. See also *ibid.*, p. 187, table 1, for a qualitative comparison of the various X-ray-imaging methods used in the study of archaeological artefacts.



Fig. 105 Xeroradiograph of a Pan-shan culture vessel, *c.* −3,900 to −3,600, from Kansu province

from Hajji Firuz in north-western Iran. The body of one Chinese vessel (Pan-shan D2669) was diagnosed as being 'made from coils, some 7–8 millimetres high' (see Figs. 105 and 106).[20] The author noted that it was difficult to distinguish coil joints in the bulbous part of the body, although these were clearly visible on one of the vessel's

[20] Vandiver (1988), p. 156. The xeroradiographs were supervised by Pamela Vandiver, who was allowed by K. C. Chang to take Neolithic vessels to Cambridge City Hospital (Massachusetts) for imaging and an overnight stay.

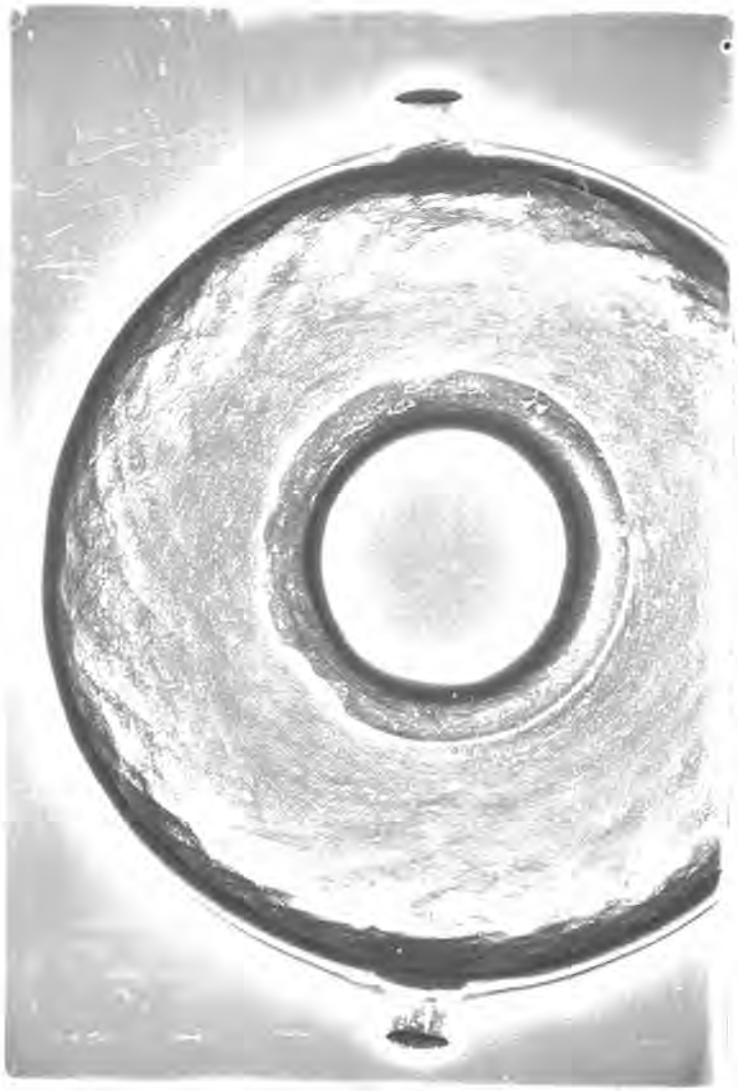


Fig. 106 Top view of vessel in Fig. 105

necks.[21] Paddle and anvil patterns could be discerned as a superimposed diamond pattern, and the lower part of the handle was not well secured as it was added in a much wetter clay than the jar after the vessel had already shrunk and started to dry.

The main making sequence for the Pan-shan jar was interpreted as follows:

the pot was coiled in sections. Following construction the body was subjected to high forming pressure with a paddle and anvil, as shown by the individual paddle marks on the

[21] *Ibid.*, p. 157.

body . . . The smooth carefully reworked surface shows no sign of the beating to which the pot was subjected . . . Following construction and shaping . . . the lower part was scraped in a diagonal direction . . . the surface was wiped, smoothed in some areas, then slipped and partially painted.

This coil-based method of construction differed markedly from that evident in the West Asian examples studied. The latter used small, overlapping and flat pieces of clay, shaped rather like large irregular scales, instead of coils. The Iranian clays were mixed with chaff to control both their stickiness and their high shrinkages, caused by the presence of super-plastic clay minerals of the montmorillonite family in the clay bodies. Tempering with chaff also gave the Near Eastern wares improved strength and stability in building. The Pan-shan wares, by contrast, seemed to have used smooth and naturally siliceous loessic clays that made fibre or other tempering additions unnecessary.

HAND-BUILDING METHODS

The 'classic' method of coiling, suggested by Vandiver as the means for making the Yang-shao culture 仰韶文化 Neolithic vessel that she studied, involves gradually adding, one ring at a time, a clay 'rope' that is about 1 centimetre in diameter or less. This is pinched and smoothed on to the growing vessel's top edge, allowing the main form of the vessel to be accurately constructed and controlled. The coiled form is then finished (in this example) by beating, scraping and burnishing.

It may be risky, however, to extrapolate from these findings to Chinese Yang-shao ceramics in general, as coiling can proceed in various ways. For example, many ceramic traditions use coils that are 3–4 centimetres in diameter (or even larger), and often made from rather soft and tempered clay. These are attached to the inside rim of the growing vessel and smeared downwards into place. With one hand outside supporting the pot's wall, and the other inside, the inner fingers then smear the clay upwards to raise the pot's size. This method gives a thinner top edge, ready for another coil to be applied inside.

With this latter method only half a dozen coils might be used on a largish vessel, while the finer method of coiling might take 50. While the forms produced tend to be initially less accurate than those made with thinner coils, skilful beating can soon correct the difference, and the method proceeds much faster than with fine coiling. Only shadowy evidence of this 'thick' coiling method would appear in xeroradiography, although any subsequent beating of the pot's walls with a paddle and anvil to refine its shape would show up well. This technique can result in a vessel that looks just like one made from narrower coils, and was observed being used for making roof tiles and small and large stoneware jars by the authors in a country pottery in Chiangsi province in +1982.[22]

[22] See Wood (1999), p. 20, for an illustration of this process, and some jars produced by it.

It is also possible to dispense with coiling entirely. Many pots world-wide are made by beating a rough ball of clay into a shallow mould, usually with a pebble, a wooden pestle, or a round lump of dry or fired clay, and then moving the pot systematically about as it is beaten in order to thin its walls. With skill this can produce a thin-walled near-spherical vessel. Large pots, a foot or more across, may be made in this way from single pieces of clay. Textured cloth or matting in the shallow mould reduces the tendency of the clay to stick and gives the vessel an overall textured surface, very similar to that seen on a coiled pot that has been finished with a hard curved object inside and a textured paddle outside. Often single coils may be applied to the rims of vessels made this way, and a skilful potter can wipe this around with a wet cloth, or thin leather, in a manner that gives a result that is easily mistaken for wheel-finishing in its regularity and general section. Thus these combined techniques may give a superficial impression of a coil-built pot that has been finished on a slow wheel, although in practice neither method has been used. Although such methods are not proposed here for the Pan-shan wares, which show shadowy relicts of coiling, they cannot be completely ruled out for Neolithic wares made elsewhere in China.[23]

Another approach can give a similar finished appearance, but completes the top of the vessel first, and leaves the making of the base to last. Potters in many cultures make thick bottomless cylinders, often with thick coils, and then make a good finished rim with a wet cloth or leather, while leaving the lower part of the vessel largely unformed.[24] When stiffened somewhat the roughly cylindrical pot is inverted, and beaten into a more spherical shape. Careful progressive beating can close the base, which is then beaten firmly to prevent cracking.

[23] Cardew (1969), pp. 91–2, describes this technique as being used in northern Nigeria by the Hausa people. A half calabash is used as a mould and wood ash is dusted inside it to prevent the clay from sticking to it. A similar beating technique with a large lump of clay is used by the Dogon people in the Malian village of Tireli. In this case a shallow hollow in a stone acts as the 'mould' and a wooden pestle, later replaced by a pebble, acts as an anvil. A single coil is again used to finish the rim and the last beating stage uses a woven mat of baobab fibre between pot and hollowed stone. The finished pots show overall fabric textures. Deirdre Wood, pers. comm. from observations made in Tireli in +1996. While hand building is often considered to be a slow method compared with throwing, this may not always be the case. For example, Simmonds (1984), p. 57, has described a similar beating-from-a-lump method at old Yelwa in Nigeria: 'The surprising thing about this technique is that the pot, apart from its rim, is finished in about 4 minutes. The wall thickness is about 2.5–3 millimetres and is amazingly consistent.'

[24] Coils are not always used to make the original cylinder needed for this method. Traditional techniques in Southern Thailand (at Sting Mor), for example, take a solid cylinder of clay and drive a wooden post down through it, first from one end and then the other. With the wooden post still in place the whole is rolled on a flat surface, which both widens and consolidates the cylinder. This is then finished 'top down', with the rim being made first. After some drying the half-finished vessel is inverted for the final beating, finishing and closing of the base, all without any kind of slow wheel. See Solheim (1986), pp. 151–61. A similar method is used in another part of Thailand (Ban Na Kraseng in western Tha Li district). Here the initial cylinder is made from one large, long slab of clay, which is bent around into a circle to make a thick cylinder, which is then drawn up from both ends with the fingertips. Making again begins with the rim and finishes with the base. See Bayard (1986), pp. 262–3. Both techniques (i.e. beating out from cylinders made from folded slabs and also from solid cylinders) have been recorded from modern Cambodia. (Cort & Lefferts, 2000), pp. 48–69. Yet another variation, this time in south-central India, uses true throwing to start the cylinder, and to finish its top rim. Sinopoli (1999), p. 123, records that these thick baseless cylinders are thrown on the wheel and then their rims are finished. The following day the lower parts of the vessels are beaten by paddle and anvil methods into near-spherical forms, and their bases beaten closed.

Thus at least three quite different making methods can give results visually identical to a vessel made by the 'classic' coiling and beating method, with its rim finished on a slow wheel. These four pathways to the same hand-built shape by no means exhaust the possibilities that are available to the hand-builder, and the anthropological literature is full of variants on these larger themes.[25]

SLOW WHEELS

The very regular beating marks seen on vessels of the Pan-shan phase of the Yang-shao culture of the -4^{th} millennium, would have benefited from some easy turning-method to assist with this rhythmic compression. In practice this can be managed by placing a vessel on a leaf, a piece of cloth or matting, or by standing it in a shallow padded basket.[26] This allows the vessel to be easily shifted slightly for the next beat of the paddle. However, even this simple turning system is not essential. In many cultures the vessel is left stationary while the potter walks around it slowly, beating systematically and developing the form.[27] But apart from being easier on the back, the advantage of sitting at a revolving turn-table is the improved uniformity and convenience that this allows in constructing coil-made vessels. This sureness in making often results in increased production. Also, because the same profile can be maintained visually during making, accurate forms are easier to achieve. A further advantage from support on a fixed axis is that rims may be smoothed more readily if the vessels are mounted on some kind of turn-table, often with the turn-table spun with one hand, while the vessel's rim is smoothed with the other.

Indications of some kind of wheel-making have been claimed for later Yang-shao wares, particularly on the rims of vessels from the late Pan-pho 半坡 phase. These signs increase in the Miao-ti-kou 廟底溝 stage of the culture, when they gradually spread to the upper bellies of the wares. The main period for this change has been placed to the later stage of the Yang-shao tradition (*c.* −4,800 to −3,600), and within an area around the middle course of the Yellow river.[28]

In the +1960s the pioneering ceramic technologist and historian Chou Jen 周仁 carried out experiments designed to explore how these making-marks on Yang-shao wares could have been made. With the help of professional potters, Chou decided that they were caused by work on the raw vessels using 'free-turning equipment', i.e. a fast wheel. The archaeologist Cho Chen-Hsi 祖振西 has questioned

[25] Good analyses and reviews of traditional hand-building methods used world-wide are provided in Rice (1987), pp. 124–44.

[26] A number of vessels from Pan-pho in Shensi province show clear imprints of woven fibre matting on their bases, see p. 7 and Kuhn (1988), pp. 61, 90–141, 157.

[27] For example, see Cardew (1969), p. 88, on water-pot making in Kwali, Nigeria: 'All this time she moves rhythmically backwards round the pot, sometimes in a clockwise direction, sometimes (as in a dance) reversing to avoid giddiness.' Rice (1986), p. 142, describes a similar making method in Guatemala, and calls this the 'drawing and orbiting' process. For another instance of static vessels and moving potters, this time from Thailand, see Bayard (1986), pp. 261–8, unpaginated photographs 3a–5b after article.

[28] Cho Chen-Hsi 祖振西, pers. comm.

this conclusion because Chou used modern throwing wheels to model the effects.[29] Mrs Cho's own ideas on these making-marks are based instead on some significant wheel-shaped objects, made from fired clay, that have been excavated from a number of Yang-shao sites in north China.[30]

CHINESE NEOLITHIC POTTER'S WHEELS

A range of wheel-shaped ceramic objects has been found in later Yang-shao sites in the north. These have been excavated at Pan-pho and at Yang-shao in Shensi province. Similar wheels have been found in Kansu, Honan and Shansi provinces. Cho Chen-Hsi does not give detailed references for these finds, but she notes that:[31]

what should be pointed out is that the above-mentioned wheels were unearthed from the same stratum together with the pottery wares with wheel marks of concentric circles. This universality is nothing fortuitous.

The forms of these 'wheels' are shown in Fig. 107. They are mostly about 30 centimetres in diameter and are heavily and thickly made, weighing some 6–8 kilograms apiece. From experiments set up by Cho it was found that they had the 'adaptability of design between balanced turning and low-speed turning.'[32]

Cho sees these wheels being used the same way up as they appear in the sectional drawings, with the vessels being finished sitting in the 'wells' of the wheels, and the potters turning the wheels from the wheels' rims. The extra mass supplied by the raw jars and bowls meant that the wheels could be made to spin freely, if necessary. In Cho's experiments one operator (a ceramics restoration worker) managed to make one loaded example turn 33 times on one spin before the wheel slowed and stopped, although ten turns at about 60 rpm were more typical. Cho writes:[33]

I regard it as the slow speed throwing wheel of the Yang-shao culture (also called 'slow wheel'). It is also the earliest throwing wheel discovered in our country.

There are of course legitimate questions still to be asked on this subject, such as: Were these wheels really used for making pottery? And, if they were, is this how they were originally used? On the first question, it is hard to see what other role could explain the shapes of these objects, unless perhaps that they were made as

[29] Cho writes: 'such conjecture and the series [of] simulated tests were apparently achieved on the basis of the traditional Chinese potters wheel (fast speed throwing wheel) that can be seen today . . . the conclusion was hardly satisfactory.'

[30] Cho Chen-Hsi's paper was presented to the Second International Symposium on Ancient Chinese Pottery and Porcelain, held in Peking in +1985. The proceedings for this conference were not published, so the quotes are from typescripts, given to the authors after the meeting.

[31] From Cho's manuscript.

[32] *Ibid.*

[33] *Ibid.* Cho's term 'throwing wheel' may be confusing here: 'turn-table' would be more apt.

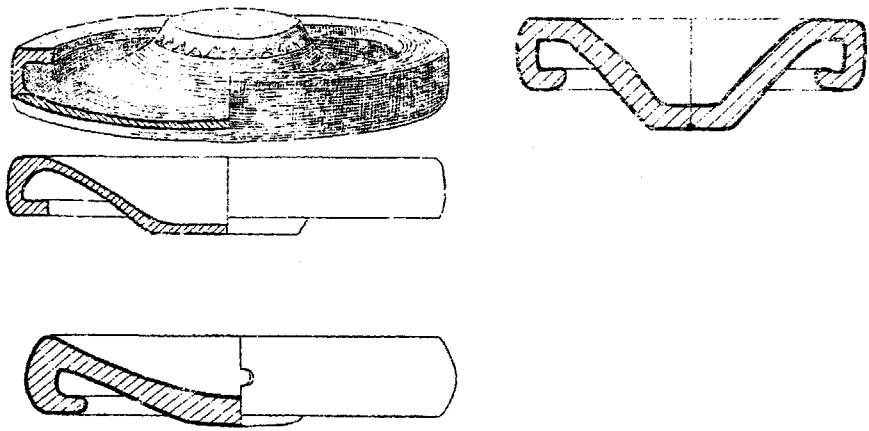


Fig. 107 Fired clay artefacts interpreted as pottery-making wheels of the Yang-shao culture. The wheel top-left is from Pan-pho

supports for hut posts, in which case their massive construction might apply. However the fact that they were burnished, and sometimes decorated, may make an architectural role less likely: excavated ceramic post-supports from the Yang-shao culture, such as those found at Pan-pho, tend to be rough, ring-shaped and massive.[34]

Their ability to spin freely would certainly have been an advantage for finishing rims, and in painting decorative bands, but for ordinary coiling and beating their ability to inch easily on a fixed path would also have been useful. It is important that Cho Chen-Hsi does not claim that these wheels were used for fast throwing, but rather that they were aids to coiling, beating and rim-finishing, perhaps in the manner revealed by the fieldwork of Cheng Zhuhai [Chheng Chu-Hai 程朱海] and his colleagues fieldwork in Yunnan in +1977:[35]

Coil-forming on a turn-table. This method is used by the Dai [Tai] 傣 people at Manzha [Man-cha 曼乍] and Mandou [Man-tou 曼斗] stockaded villages . . . The turn-table, made up of a wooden plate pivoted on a stand, is rotated by the toe. The forming speed and the roundness of the vessels is much improved. Archaeological studies show that this kind of turn-table is very similar to the "slow-wheel" popularly used in the Yang-shao culture.

DECORATION

Cho Chen-Hsi sees a further use for these wheels, to aid the production of the painted decoration that is one of the most remarkable features of Yang-shao

[34] A ceramic hut-post support is illustrated in Anon. (1987b), fig. 15. The authors note that pebbles and sherds were rammed down into the base of post-holes.

[35] Cheng Zhuhai *et al.* (1986), pp. 30–1.

hand-built earthenwares. Notable are vessels from the north-western outposts of Yang-shao culture, in what are now Kansu and Chhinghai provinces. A freely turning wheel would certainly have been essential for the very regular, banded decoration that appears on later Yang-shao wares from Kansu province. In some examples these bands can form the main designs, but more usually they divide the vessel into zones that are completed by freehand painting.

It is a noticeable feature of Yang-shao ornament that it tends to leave considerable areas plain and unpainted towards the foot of the vessel. This has sometimes been taken as a sign that the wares were intended to be regarded from above, as they stood on hut floors, or were set in pit-burials.[36] However, the possibility that the vessels were placed in the wells of deep pottery wheels for decorating should also be borne in mind, for this would have made the lower parts of the vessels inaccessible for banding. It may also be significant that when painting on Yang-shao culture pottery lacks this kind of accurate horizontal banding, and the decoration is entirely freehand, it often covers the entire form.

Perhaps the most intriguing possibility, suggested by the shapes of the wheels, is that they may also have acted as moulds, to start the forms of the pots and bowls, and also to support them initially in making. The shapes of Yang-shao vessels can be extreme, with their lower halves often convex rather than straight or slightly concave. These would have been difficult shapes to start with in conventional coiling, and also rather weak beginnings for taking the weight of extra coils.[37] Successful making with these forms would certainly have benefited from some kind of support in the early stages of manufacture.[38]

From Slow Wheel to Fast Wheel

It is perhaps the abundance of accurate banded decoration, more than anything else, that suggests that some freely spinning tools were used for supporting Yang-shao ceramics in the Chinese Neolithic.[39] Even if the 'wheels' described by Cho Chen-Hsi had some function other than for making pottery (which seems unlikely) some free-turning equivalent must have been developed for painting the regular fired-on

[36] Huber (1983), pp. 177–216; Barnes (1993), p. 103.

[37] Such forms are more common on hand-built vessels made by the 'top-down' method, where the lower part of the vessel is gradually beaten inwards to make a closed base.

[38] A more usual candidate for moulding, often proposed for Chinese Neolithic ceramic construction, are the three hollow udder-shaped legs seen on trilobate cooking vessels and ewers, common across the Chinese Neolithic world. Although these forms tend to be associated with China, Masuda Seiichi points out that these vessels were: 'not peculiar to prehistoric Chinese culture, but were distributed over a wide area ranging from Mongolia and China to northern Iran. . .'. Masuda Seichi (1969), pp. 3213–19. The suggestion made is that the hollow mammiform legs on the Chinese vessels were sometimes formed around some kind of mould. This may have been the case, but a problem with that idea is that on most examples the hollow legs are curved rather than conical. This would have made extraction of any mould difficult, once the legs had been formed. Even so, initial moulding followed by a filling-out of the shape by beating cannot be ruled out.

[39] A burnished hand-built jar from Kansu or Chhinghai provinces (Ma-chia-yao 馬家窯 Pan-shan culture) dated to the mid –3rd millennium, with 22 parallel painted bands, is illustrated in Krahl (2000), p. 65.

bands of ochres and umbers seen on these wares. The usefulness of such turn-tables for finishing rims and the upper parts of vessels while they were still in their plastic states may well have led to the design of larger and heavier wheels that were suitable for more continuous operation. These heavier wheels could have been used for smoothing small coil-built wares, while the clay was still soft. In fact 'transitional' wheels of this postulated type emerged from the Yunnan field study of +1977. These were not quite true throwing wheels, but were very close to this condition:[40]

Coil forming and throwing on a heavy wheel. This method is used by the Dai (Tai) nationality at Manlang (Man-lang 曼朗) Stockaded Village . . . The plate is thick and heavy and can be rotated freely and continuously due to its own weight, though it may not have enough inertia to allow forming entirely by throwing. The rotation of the wheel is controlled by toe or hand. Pottery vessels made by this method usually bear wheel marks on rims or surfaces. This kind of wheel is very similar to the 'quick wheel' of the Yang-shao culture.

In the illustration supplied to the paper, the wheel appears some 60 centimetres in diameter and more than 5 centimetres thick. The potter is spinning the wheel with his left hand and throwing one-handed with his right, compressing the clay between extended fingers. This clearly shows how pots that have been started by coiling may be immediately finished by throwing, a technique still common in Japanese country potteries where poorly plastic clays and rather light wheels encourage some use of the method.[41] In this kind of throwing the repetitive pinching used to thin and consolidate attached coils is replaced by making the clay run through a gap between the fingers, using water splashed on the clay to stop it sticking. This is true throwing, as it compresses, thins and raises the vessels' walls, all in one operation.

It is also worth adding that pots that have been started by throwing can, after some stiffening, be added to by coiling, and then the coils compressed further by throwing in such a way that all evidence of coiling disappears, even to xeroradiography. Finally the whole vessel might be finished by beating, a process observed by the authors at Shen-hou 神堠 in Honan province in +1985.[42] Such hybrid methods, however, are more often used with larger vessels. Throwing in its simplest and 'purest' form usually starts with a ball of clay, which is thrown smartly on to the spinning wheel head to make it stick, then wetted, and formed by pressure to make its shape. The processes of throwing and turning are described in Part 1 of this volume, on pp. 66–73.

THE ORIGINS OF THROWING IN CHINA

In +1962 and +1963 32 tombs of the mid to late Ta-wen-khou culture 大汶口文化 were excavated near to Chhü-fu 曲阜 in Shantung province. These were dated to

[40] Cheng Zhuhai *et al.* (1986), p. 31.

[41] Moeran (1987), p. 32, writes of the Japanese pottery town Sarayama 皿山 near Onta 小鹿田: 'Ever since Sarayama was founded, back in 1705, potters have made use of the coil-and-throw method. Ever since then they have been using a local clay which has been best served by this type of forming.'

[42] This modern blackware workshop in Honan province is illustrated in Wood (1999), pp. 132 and 145.

c. −3,000, and have been claimed as containing the first Chinese ceramics to have been made on a fast wheel.[43] A finely made yellow-buff trilobate ewer, apparently constructed from thrown sections, was among the finds, and this does give an impression of full-fledged throwing.[44] This claim would place early throwing in China to a period slightly later than the earliest known throwing in the Near East, where a potter's wheel weighing about 20 kilograms, 75 centimetres in diameter and 5 centimetres thick, has been found at Ur in present-day Iraq, and dated to about −3,000.[45] Some wheel-made pottery from the same area has been dated to the −4th millennium.

THE THROWING AND TURNING OF LUNG-SHAN CULTURE WARES

In the history of technology it often happens that some of the finest examples of a new technique occur soon after its discovery, when its possibilities are still being explored, and excitement with its potential is still fresh. This is certainly true for China, where some of the best examples of throwing and all-over turning in the history of world ceramics occur in Neolithic wares of Lung-shan culture 龍山文化 type, dating to the −3rd and −2nd millennia. Particularly noteworthy are Neolithic carbonised blackwares from Shantung province. These are some of the earliest Chinese ceramics to have been thrown direct, and are sometimes called 'eggshell' wares. They must have been made on fast wheels and are often turned overall until they are only some 1–2 millimetres thick. Their forms can be both complicated and extreme, and they are also remarkably light in weight, with one stem-cup seventeen centimetres tall having recently been found to weigh only 80 grams.[46] Lung-shan culture blackwares tend to be small in scale (usually less than 25 centimetres in height), so the wheels used to make them need not have been massive. The fact that no wheels from this culture have yet been discovered may mean that they were made from wood, rather than from the fired clay suggested for the Yang-shao culture.[47]

Besides fine throwing and fine turning, Lung-shan culture potters making blackware used two further advanced methods for making. These were the successful joining of two or more thrown and turned sections, and the use of fine perforations,

[43] Anon. (1993), Institute of Archaeology, Chinese Academy of Social Sciences, p. 54. The skeletons at this site showed 'the peculiar custom of extracting the upper side incisors, artificial [ly] deforming the occipital bone and keeping one or two stone or pottery balls in the mouth with the mandible deformed as a result.' *Ibid.*, p. 54. These practices were widespread among the people of the Ta-wen-khou culture in the Shantung region. See Anon. (1992b), Archaeology Department of Peking University, p. 40.

[44] Anon. (1993), Institute of Archaeology, Chinese Academy of Social Sciences, p. 54.

[45] Simpson (1997b), p. 50.

[46] Krahl (2000), p. 79. This Lung-shan culture vessel from Shantung province was dated to the second half of the −3rd millennium.

[47] As with sharks and teeth, all that tends to remain of potter's wheels at Chinese archaeological sites are the hollow porcelain or stoneware top bearings of the large wooden wheel-heads. However, this applies to later wheels. Neolithic clays would have been too soft for making useful bearings, so these may have been made from stone, and perhaps not recognised as wheel-bearings in excavations.

particularly in the stems of tall footed-cups, and sometimes on a scale that has to be measured in millimetres. These various elements are seen at their most advanced in wares from the second half of the -3^{rd} millennium, and from districts in Shantung province such as Jih-chao county 日照縣. Many examples are carbonised to give overall black effects, and the wares are often burnished (apparently while still on the wheel after turning) to give shiny black surfaces. In a few examples burnishing has been applied selectively, to give matt and shiny zones on the exteriors of the same vessels.[48] Bagley describes these vessels as 'wonderfully impractical' and showing 'hints of ritual purposes'.[49] These north-eastern blackwares are among the most accomplished Neolithic wares in the world and their strongly metallic spirit has been noted by many writers, although evidence for any beaten-metal prototypes for these, often extraordinary, shapes has still to emerge.[50]

Contemporary with these fine blackwares are some robust (but equally well made) pale-bodied ewers from the same district, some of which appear to have used kaolinitic clays in their construction (see pp. 120–1).[51] Some of these trilobate ewers were constructed from joined thrown elements, and are particularly sprightly versions of earlier hand-built examples of similar style. Neolithic ceramics from Shantung province are among the most varied, inventive and finely made in China, and include a range of handled ewers and cups that show a surprisingly modern spirit in their designs.

HANDLES

Strap handles are common on Chinese Neolithic wares and there are three practical ways in which they could have been made. One method is to roll out, or cut out and then flatten, a strip of clay, and then to smooth this further with a material such as wet leather. This finishing stage allows the potter to refine the handle's cross-section with details such as a central ridge, or finer edges. After stiffening somewhat, the handle can be bent and attached to the leatherhard vessel with slip or with sticky clay.

A related method is known to potters as 'pulling a handle'. In this technique the potter holds up a short thick length of wetted clay with one hand, and uses the other to stroke the clay downward into a long tongue. To the observer it appears as if the clay is being pulled downward into a smooth and even length, but, as with most clay-working methods, the technique is compressive rather than elastic, as clay cannot be stretched to any useful extent.[52] Pulling allows tapering handles to be produced easily, although handles with parallel sides are also possible. Central ridges and fine edges are easily achieved by changing the position of the thumb during the 'pulling' action. Both making methods can produce similar-looking handles, and it

[48] Krahl (2000), p. 82.
[49] Bagley (1987), p. 25.
[50] Medley (1976), p. 25; Vainker (1991) p. 25.
[51] Luo Hongjie (1996), database. A fine example is the Arthur M. Sackler Museum of Art and Archaeology, Peking University. See Anon. (1992b), Archaeology Department of Peking University, pp. 80–1, fig. 27.
[52] See Cardew (1969), fig. 37, for a photograph of the method, and pp. 112–13 for a practical account.

is by no means easy to tell which has been used for the more regular-looking handles on Chinese Neolithic wares. What is obvious, though, is the way the Neolithic handles are usually reinforced at the points of contact with small amounts of extra clay, and this provides both practical and visual strength to the attachment.

This 'pulled or smoothed' problem applies also to the large solid-clay tripod feet seen on so many Chinese Neolithic wares. These solid legs usually taper, which suggests 'pulling', but a faint underlying irregularity also hints at rolling (and/or flattening), followed by smoothing. Perhaps the question here is not so much which method was used for a particular piece, but whether the 'pulling method' was ever employed to make handles or feet for Chinese Neolithic ceramics. While it is hard to find examples that unequivocally speak of the technique, it is equally difficult to conclude that the method was never used.

A third method for making handles for Chinese Neolithic wares involves throwing vessels without bases, and cutting these thrown rings into sections suitable for handles. This has been described for middle Lung-shan period pottery from Liang-chheng-chen 兩城鎮 village in south-east Shantung province:[53]

> Handles were thrown in a stack as a cylinder and separated with a needle-tool into rings . . . Each ring was then divided into . . . two or three sections, each to be used as a handle.

A similar method was used to make tall C-sectioned feet for large semi-cylindrical jars, in this case the bases were removed from thrown cylinders and cut vertically into halves, which were then attached with sticky clay to the bases of the jars. Both techniques illustrate the highly inventive and skilful working practices of Shandong Lung-shan potters, and these highly successful and stylish thrown handles in particular are virtually unknown in later Chinese ceramics.

Liang-chu Culture 良渚文化 Blackwares from South China

Superficially similar to Lung-shan blackwares, but now believed to be the products of an independent and important southern cultural tradition, are the finely thrown blackwares of the Liang-chu culture, named after a site near Hang-chou in Chekiang province, and first excavated in +1937.[54] Nearly a score of Liang-chu culture sites have now been found in Chekiang province, particularly in the Hang-chou Bay area. Those sites produced similar wares, which included some thinly thrown and turned covered jars. Like the black Lung-shan vessels from Shantung province, they often have fine perforations on their feet and covers.

Liang-chu blackwares can now be seen as developments of the earlier Ho-mu-tu 河姆渡 culture, with its extensive stilted villages and developed Neolithic lifestyle that included rice harvesting, the use of pig, dog and buffalo, and such advanced

[53] Vandiver *et al.* (2002), p. 579.
[54] Report quoted in Li He (1996), pp. 25, 339.

features of material culture as the use of lacquer.[55] The large Neolithic village at Ho-mu-tu in Yü-yao county 余姚縣, Chekiang province, was discovered in the summer of +1973, and excavated in the winter of the same year, and again in +1977. The 2,800-acre site has produced evidence that has become as important to the understanding of southern Neolithic life, as the Pan-pho site in Shensi province proved to the understanding of the Neolithic north. The earlier stages at Ho-mu-tu are roughly contemporary with those at Pan-pho.[56]

The technical difference between Liang-chu and Lung-shan blackwares is that charcoal was added to the Liang-chu clays before making, an 'internal' rather than 'external' carbonising approach, apparently inherited from earlier Ho-mu-tu ceramics.[57] Xeroradiography of Liang-chu ceramics shows clear evidence of throwing, particularly in the stems of tall cups, where the characteristic 'wreathing' inside the cup-stems indicates that potter's wheels were used, and that these revolved in the counter-clockwise direction.[58]

[55] Chang Kwang-Chih (1963, 1986), p. 212. Neolithic lacquer is displayed in the Chekiang Prefectural Museum in Hang-chou.

[56] The fourth cultural level at Ho-mu-tu has been C^{14} dated to 7,000 b.p. (*c.* −4,950), with occupation until *c.* −3,400. Li Chia-Chih *et al.* (1979), p. 112. The dates suggested for Pan-pho are *c.* −5,000 to −4,000, see Anon. (1993), Institute of Archaeology, Chinese Academy of Social Sciences, p. 12.

[57] Li Chia-Chih *et al.* (1979), p. 112, write of the black Ho-mu-tu wares: 'The mixed carbon-blackwares, excavated in large quantities were made of a kind of clay containing sericite intentionally mixed up with carbonized rice husks, stalks and leaves, which were burned beforehand.' See also Dajnowski *et al.* (1992), p. 618.

[58] See Dajnowski *et al.* (1992), p. 612, fig. 3. The rippled spiral marks known as 'wreathing' tend to occur inside thrown vessels that have been collared during making, i.e. compressed from the outside without supporting the clay inside. The underlying spiral that is present in all thrown vessels then becomes very evident. This spiral effect tends to be exaggerated by air pockets in the clay, which are extended and given spiral form by the upward and dragging action of throwing.

BRONZE AGE TECHNIQUES

CLAY-WORKING IN SHANG DYNASTY BRONZE-CASTING

e attention lavished on fine ceramics during China's Neolithic period waned h the coming of the Bronze Age, and the quality of ceramic design, finish and ıament all declined in China with the advent of bronze. Interest in ceramics ms to have been eclipsed by this new bronze-casting technology, particularly ough the making of ritual vessels. Paradoxically, because of the clay-based :ure of Chinese bronze-casting, by far the most sophisticated techniques used in formation and manipulation of clay were practised by Shang dynasty bronze-ters rather than by potters. These advanced clay-working techniques were devel-ɔd to make the original solid models for cast bronze vessels, and also for the ·amic piece-moulds taken from them. Clay core-making was part of this same hnology, and was a process at least as specialised and demanding in its operation the making of models and moulds.

Although the precision, planning and technical skill needed for clay-working hin the bronze industry surpassed anything used in the production of Shang ıasty ceramics, the models, moulds and cores used in the foundries were merely ges towards the making of cast vessels. The pouring of the molten bronze (taking ly a few seconds) was the climax to the operation and models, moulds and cores re discarded once the vessels had been cast. First-hand evidence for the sophisti-ion of Shang dynasty clay-working skills can be seen not only in the ceramic ɔris excavated from bronze-foundry sites, but also in the scale, the complexity d the fine ornament of the bronzes themselves. It seems that clay moulds for ɔnze-casting superseded the earlier stone moulds that were mainly used for cast-; tools and weapons in the pre-dynastic period.[59] Although the application of ·amic piece-moulds to metal casting had been anticipated in the Near East (in ɛsopotamia) the method was developed in China to unprecedented degrees of mplexity.

MODEL-MAKING

ɨpiration for the forms used for China's first cast bronze vessels owe much to late ɔlithic ceramic design, as well as to vessels made from beaten and joined sheet-ɛtal. Nonetheless, the relative contributions of these two sources cannot be

[59] Muhly (1986), pp. 14–15.

entirely disentangled, as beaten metal designs may have influenced ceramics to some degree and vice versa.[60]

The net result is that the first cast bronze vessels made in China, such as *chüeh* 爵 from the Erh-li-thou 二里頭 period (*c.* −2,000 to −1,500), have rather fine and complicated shapes, with their thin sides and thickened rims evoking the character of beaten and joined sheet-metal.[61] By the Erh-li-kang period 二里崗 (*c.* −1,800 to −1,400) bronze-founders in Honan province were copying the *ho* 盉 pouring vessel, one of the most difficult of all forms to translate into cast metal. By choosing to make these vessels entirely by bronze-casting, Shang dynasty founders set themselves formidable tasks in the construction of clay models and moulds. Not only were the forms that they imitated elaborate in themselves, but the thinness of their walls also meant that the cores had to follow the topology of the outer moulds exactly, typically with only a 1–3 millimetre gap between. Surviving bronzes from the Erh-li-thou and Erh-li-kang periods suggest that all the necessary skills in mould and model-making were in place at this time, although the use of surface ornament was still rudimentary.

It was perhaps the need to avoid casting holes in thinly cast bronze vessels, through ill-matched moulds and cores, that encouraged the dimensional precision that became central to Shang dynasty model-making and mould-taking technology. Molten bronze of course has no form of its own, for it is simply a liquid that follows the contours of the casting-moulds exactly. What was needed to achieve the necessary accuracy of execution were model-making and mould-taking methods that could realise the bronze-founders' visions perfectly, thus eliminating the natural variations that are inherent in beaten metal vessels or in hand-built ceramics. From these models, moulds needed to be taken that reproduced these 'ideal' forms exactly. A key element in the successful resolution of this problem was a method for constructing mathematically precise solid originals from plastic clay through the use of simple mechanical jigs. In retrospect, we can see that the development of this principle was as important to the success of Shang dynasty bronze-casting technology as the potter's wheel became to Lung-shan ceramics.

JIGS IN CLAY-FORMING

The potter's wheel is a kind of jig, in that it spins a lump of clay on a fixed axis and allows pressure to be applied to the spinning clay, squeezing it upward into a hollow form.[62] All thrown forms are therefore round in horizontal section, although once thrown some distortion is possible in both the plastic and leatherhard states. One of

[60] 'The Chhi-chia 齊家 repertoire of pottery shapes shows a pervasive influence from vessels of hammered metal, and if the radiocarbon dates are to be trusted these metal vessels were known in China by the beginning of the second millennium.' Bagley (1987), p. 16.

[61] K. C. Chang writes: 'These vessels are small, thin (about 1 millimetre), plain, and flat bottomed, but the seams indicate that they were cast in at least four piece molds.' Chang Kwang-Chih (1980b), p. 37.

[62] A jig can be defined as: 'A device that holds a piece of work, and guides the tools operating on it.' *Concise Oxford Dictionary* (1995), p. 730. See also Pye (1964), pp. 53–5, for a discussion of jigs in general.

the most remarkable features of Shang dynasty bronzes is the way that the cross-sections were not only round, but square, oval, rectangular or even triangular, with many intermediate shapes (such as rectangles or diamonds with rounded corners) employed as well. When these complex cross-sections were combined with the elaborate profiles typical of Shang dynasty bronze-vessel design, the complexity of the three-dimensional forms that resulted were remarkable, and eventually led to a highly distinctive cast-bronze style. After an initial phase, when forms were borrowed from other materials, Shang dynasty bronze-founders devised a range of vessel-shapes that used mechanical precision and volumetric complexity to achieve the powerful physical presence that is so characteristic of Shang dynasty bronze-casting, especially in its mature stage, the An-yang 安陽 period.

THE RUNNING PROFILE

Although the literature on the technology of Shang dynasty bronze-casting is extensive, particularly with regard to ornament, alloy compositions and the details of mould-arrangement in casting, the subject of model-making has been less well studied.[63] One of the authors was brought face to face with this problem in a practical way in +1989 when commissioned by the British Museum to copy a Shang dynasty bronze *hu* 壺, using authentic casting methods.[64] The vessel was oval in cross-section with a tall hollow foot and with lugs on its side.

When rotated slowly on a turn-table the profile of the *hu* appeared quite constant, which suggested that a rigid and shaped profile had been used to make the model, jigged against rigid oval cross-sections, set at the top and the bottom of the form. There was also evidence that the profile had been used in a dynamic way to create the model, rather than simply to check its geometry as it was built up by stages. This was suggested by three raised parallel lines around the neck of the vessel, and also three fine parallel channels on the vessel's body, used to organise the decoration. This meant that the moulding material had been formed directly by the profile as it was swept around the fixed cross-sections, with nicks in the profile providing the raised lines on the model, and small projections leaving shallow parallel channels.

Thus, by placing rigid cross-sections at the top and bottom of a post, packing plastic clay around this upright, and then sweeping the profile around (while keeping it in continuous contact with the oval cross-sections) a solid three dimensional form could be rapidly created. The form was complete with parallel 'bowstring' lines, and fine channels that could serve later as guide-lines for carved free-hand ornament.[65]

[63] Some key texts on the subject of Shang dynasty bronze-casting technology are: Fairbank (1962), pp. 9–15; Gettens (1969), pp. 205–17; Smith (1981), pp. 127–73; Chase (1983), pp. 100–23; Meyers & Holmes (1983), pp. 124–36; Bagley (1987), pp. 38–143; Meyers (1988), pp. 283–95; Muhly (1988), pp. 2–20; Bagley (1990), pp. 6–20; Holmes & Harbottle (1991), pp. 165–84; Chase (1991); Chase (1994), pp. 23–37; Su Jung-Yü *et al.* (1995), pp. 17–20; Hua Chüeh-Ming (1999), pp. 81–135; Than Te-Jui (1999), pp. 211–50. Some of these texts do not mention model-making at all, while others merely say that models were produced – and then proceed to discuss mould-taking.

[64] Reconstruction of this vessel is described in Wood (1989), pp. 50–3.

[65] See Wood (1999), p. 15, for a photograph of this operation.



Fig. 108 Nigel Wood using the 'running profile'

This simple tool, developed for making the solid clay models for Shang dynasty ritual bronzes, took their makers into new worlds of form, and gave Shang dynasty bronzes a formal character that became quite distinct from clay vessels, despite the original models for the bronzes being made from clay. As Robert Bagley notes:[66]

> The dramatic changes effected in the vessel shapes in the course of the Shang dynasty period were achieved without any essential change in method.

MOULD-TAKING

While the types of clay used for model-making are still unknown, Shang dynasty casting moulds have been shown to be fired loess.[67] Some examples studied by scanning electron microscopy appear to have had their finer and more plastic fractions removed by washing, perhaps to minimise their shrinkages in drying and firing and to maximise their porosities to entrapped gases in the molten alloys.[68] Even in its unwashed state, however, loess was probably unsuitable for model-making. Many Shang dynasty bronzes bear ornament that is as fine as a fingerprint, and which must have been carved into the original models when the clay was leatherhard.

[66] Bagley (1987), p. 25.
[67] Freestone *et al.* (1989), p. 265.
[68] Wood (1999), p. 14.

Although loess is quite capable of picking up this kind of detail when pressed against a model, its siliceous and silty nature makes it unsuitable for direct carving.[69] Loess may also have been too weak to withstand the dragging action of the 'running profiles' without breaking from its support. The tough, waxy, sedimentary stoneware clays of northern China would have been far more suitable for these roles.

SHANG DYNASTY MOULDS

As described on pp. 102–4, Shang dynasty bronze vessels were cast using some kind of ceramic core surrounded by multiple-section ceramic moulds, with simple joints set on the mould-edges to assist rebuilding and relocation of the outer mould-shells. Bronze spacers were set between moulds and cores to maintain the vessels' thicknesses in casting, and these are often visible in X-rays of Shang dynasty bronze objects, made from at least the Erh-li-kang period onward.[70] Once assembled, the bronze was poured between outer-moulds and cores. Moulds, spacers and cores were probably firmly bound and/or nearly buried in sand or loess. Most Shang dynasty vessels were cast upside-down, from their foot-ends, both to provide support for their major cores, and also to restrict casting-scars to the feet. Moulds and cores could only be used once as the cores were either broken out from the vessels after casting or were left *in situ* if inaccessible, for instance inside handles or within the legs of *ting* 鼎. Some of the detail from the outside moulds could become stuck in the bronze's ornament during casting, and had to be removed by fettling, making reuse of the outer moulds impractical.[71] Whether models were ever reused is a moot point. Bagley, for example, believes that this was never done,[72] although it is highly probable that the same jigs and strickles were reused to create identical plain forms, but with their freehand ornament differing in detail.[73]

Once the solid model had been 'swept up' by the profiles and allowed to stiffen somewhat, it received its carved ornament and any extra details such as handles or *thao-thieh* 饕餮 heads were made, stuck on, and fettled. The model was now a solid original of how it would appear when cast, although fractionally larger. The outer casting-moulds could now be made from the model, though how this was managed is still a matter for speculation. The conventional wisdom is that the whole model was covered with loess, which was allowed to stiffen, and then cut into suitable sections. These were allowed to stiffen, removed, reassembled and allowed to dry.

[69] 'On the mould surface the draftsman naturally wants fine clay capable of taking fine details; the foundryman on the other hand prefers coarser, tempered clay, which gives a porous mold and allows the escape of gases evolved during casting . . . The tempered clay of a mold could in other words be impressed with a design more satisfactorily than it could be carved.' Bagley (1987), p. 39.

[70] Gettens (1969), pp. 98–107; Bagley (1987), p. 42.

[71] Even if only one mould section were damaged, this would render the rest unusable.

[72] 'There is no evidence of . . . duplicate castings among Shang dynasty vessels. Paired vessels identically inscribed and decorated typically show differences in detail that imply molds prepared independently.' Bagley (1987), p. 40.

[73] 'Strickle' is the foundry term for a profile used in mould-making.

This, however, may be rather too simple an interpretation of the process. It ignores the fact that the side-joints on surviving mould fragments seem integral to the sections and not added later,[74] and that using a knife to cut through to the model would have damaged the model's surface, an effect that would have been visible on the final casting. Most important of all, it would have been impossible to cut 'blind' through the applied thickness of loess in such a way as to give the extremely precise sectional divisions that are just evident on some finished vessels, and very obvious on surviving mould fragments.

All this means that the outer mould sections were most probably built up individually, and sited exactly where they were needed, with the side-joints between the mould sections made as part of this process. This could have been achieved by using vertical 'walls' of fine and stiff clay to define the mould edges, between which the loessic mould-material could have been pressed. These walls would have incorporated dents or projections to create the mortise and tenon elements that became side-joints on the mould sections. When stiff enough to handle the mould sections would have been removed and dried. Once dry they were fired to sufficiently low temperatures to avoid firing shrinkage, and to allow the material to absorb gases from the molten bronze, while still being strong enough not to be damaged when reassembled for casting. Firings to about 800–900°C would have met these aims.

THE CORE

Many authorities suggest that the vessel's original model, scraped clean from ornament, and reduced appropriately in size, served as its core in casting.[75] This seems unlikely for various reasons:

- The tough plastic clays, most suitable for model-making, would have made poor core materials. They would have lacked suitable porosity, and also resisted the shrinkage of the cooling bronze, even causing the vessel to crack.
- It would have been difficult to remove the supporting post from the centre of the model, as the shrinking and stiffening clay would have tightened around it.
- The cores are not simply the models reduced: they often involve considerable 'spares' that locate with the outer mould sections. These would have represented substantial and impractical additions to the original models – had they been pared down to make the cores.

It seems possible that major cores were pressed either from fired outer moulds themselves (perhaps with some suitable lining inserted to represent the intended

[74] See, for instance, the well-preserved sections of a Western Chou dynasty *ting* 鼎 mould in the Lo-yang Museum, Honan province, illustrated in Anon. (1990b), p. 43, fig. 16.

[75] For example, see Smith (1981), p. 130; Chase (1991), p. 115; and Meyers & Holmes (1983), p. 125. In their paper Meyer & Holmes (p. 125) describe one pre-An-yang *chia* 斝 that: 'carries literally the imprint of a ceramic model on parts of its interior wall', and claim that: 'this *chia* provides the first direct evidence of the use of a scraped down model'. This seems to ignore the possibility that cores taken from outer casting-moulds would also show ornament, before they were appropriately reduced in size to make casting-cores.

thickness of the bronze),[76] or that they were pressed from an especially made set of plain moulds. With this latter technique, plain vessel-models, slightly smaller than the decorated versions, could have been 'swept up' and plain outer moulds taken from them. Once assembled hollow cores could have been pressed inside them, using a soft and porous moulding material that would be crushed easily by the cooling bronze.[77] It may not have been necessary to fire these temporary 'core moulds', nor even the cores taken from them.[78]

It is noticeable that where relief ornament appears on Shang dynasty bronzes, the inside surfaces of the vessels tend to follow these outer contours. This may suggest that the cores were taken from the fired moulds, or it may simply be that the core-makers took great care to keep their bronze-sections constant.

In fact the difficulties that we have today in interpreting exactly how Shang dynasty model-mould- and core-making proceeded, serves to underline the enormous subtlety and complexity of thought and planning that the industry involved. This is something quite apart from the technical execution of the principles devised, which also shows quite exceptional skill in its resolution. The highly ritualised nature of Shang dynasty society may have been helpful here, as complex craft processes are akin to a religious rites, where all the stages are strictly set out and followed, in the hope and belief that the final outcome will be successful.

ORNAMENT

Many very early Shang dynasty bronzes were plain, but a few were decorated by direct carving into the inside faces of the mould sections. These designs were simple (mainly lines and dots) and appear now as 'thread relief' on the outsides of the vessels. A similar 'drawn in the mould' approach to bronze decoration was used on some later Shang dynasty period bronze vessels from south China, and many early Japanese bronze bells show similar decoration, in the form of raised lines and hatching.

In northern China this approach was soon superseded by the much more convenient method of direct carving on to the surface of the model, as well as modelling this surface with added details. In this case the ornament could be executed the correct way around, and would appear on the bronze exactly as seen on the model.

[76] An objection to this first idea lies in the likelihood of damage to the unused casting-moulds during the core-pressing operation. Ornament engraved on the model would appear as fine thread-like lines on the inner mould surfaces, which would easily be damaged during pressing. There is also a risk that the mould edges would chip during assembly and dis-assembly when core-taking was in process. However, if a *second* disposable set of moulds were taken from the original model then these objections would not apply. These 'core-making' moulds would not necessarily have needed firing.

[77] One of the few description of true core material from north China's early Bronze Age comes from Barnard & Cheung (1983), p. 370. The core material they studied was 'a clay-straw-like fibrous material' and containing 'lumpy blobs of charcoal. Baking the core has resulted in much of this disintegrating and leaving a highly porous texture'. Such a material would have been unsuitable for model-making.

[78] If raw cores were heated to 200°C+ for some time before the casting-moulds were set up then risks from steam-explosions could be avoided.

There were few limitations as to what could be achieved with this technique, the main constraint being that undercuts complicated mould construction inordinately, so tended to be avoided where possible.[79]

The great convenience of this method must have encouraged the accumulating amount of detail that appears on later Shang dynasty and Western Chou dynasty bronze vessels. Bronze-vessel ornament reached its zenith of complexity during the Eastern Chou dynasty at the Hou-ma 侯馬 foundry in the state of Chin 晉, when highly intricate interlaced decoration, often operating on more than one plane, came to be used. This period also represents the peak of sophistication of Chinese clay-based Bronze Age mould-making techniques. The designs in this case were *not* formed directly on the solid models, but were set into the mould-faces themselves, rather like printer's type in a frame, with the difference being that the various mould-elements were stuck into the larger mould sections with slip, rather than clamped in place. Why such a difficult process should have been developed is not immediately obvious, but it may have owed something to the time taken to decorate the more elaborate types of bronze vessels.

Eastern Chou Dynasty Clay-Working Techniques in Bronze Foundries

It is generally believed that decorated Shang dynasty bronze vessels were unique and had no exact companions, and that separate models, outer moulds and cores were made for each object. Forms may have been very similar, but each model would have been decorated separately. In fact the most time-consuming part of the process was probably the decoration of the model's surface, both by carving and through the addition of raised details.[80]

The Eastern Chou dynasty mould-making technique described above managed to accelerate this decoration process by an ingenious but technically demanding system. By using special outer mould sections that could take small press-moulded elements, rows of these small elements could be built up into much larger interlaced designs. In this way small details of the complicated interlace patterns could be pressed from reusable master-moulds and gradually set side-by-side on the inner faces of the larger mould sections. Thus a mosaic of highly detailed and conjoined elements could be assembled on the outer moulds' inner faces, without any ornament having been applied to the model at all.[81]

[79] This was not a total inhibition to the use of undercut ornament, that could be achieved by incorporating pre-cast bronze details within the final casting-moulds. As Robert Bagley notes of a famous, ~12th-century four-ram's head *tsun* 尊 from Hunan province, that is 58 centimetres in height: 'The fabrication of the zun [tsun] thus involved twenty-one separate casting operations, the twenty pre-cast pieces being locked in place during the casting of the twenty-first.' Bagley (1990), pp. 11–12.

[80] My own experience (NW) is that model-making and mould-taking can be accomplished in hours, while detailed decoration can take days.

[81] For a fuller analysis of this process, see Jay Xu in Anon. (1996a), Institute of Archaeology of Shanxi Province, pp. 78–9.

The difficulties in practising these advanced clay-working methods must have been formidable. Not only did all the pieces have to be sited exactly to make the larger patterns, but all the joins between the separate elements also needed disguising – and all this on a design which itself was of extraordinary fineness. The carry-over to the next outer-mould section also had to be perfect and indistinguishable on the final casting. That such an approach was preferred to direct modelling of the model's surface is a measure of how elaborate and time-consuming surface decoration on Bronze Age vessels had become. It may be significant that most vessels made at Hou-ma were round in section, which may have simplified construction to some degree.

Besides the accuracy developed for Shang dynasty clay-working techniques in the bronze industry, the scale of the moulds must also be considered. The largest northern bronze is from the later Shang dynasty An-yang period. It is known as the *Ssu Mu Wu Fang Ting* 司母毋方鼎 and is presently in the National Museum of Chinese History, Peking.[82] Weighing 832.84 kilograms and standing 133 centimetres tall, this vessel must have needed moulds at least 30 centimetres taller than the *ting*, giving mould elements (whether whole or joined) some 1.5 metres in height. Experience gained from casting large bronzes must have been valuable in the later Bronze Age, when large press-moulds for ceramic figures, architectural units and pottery vessels needed to be made.

Ceramic Moulds in Iron-Casting

A further step in the industrialisation of north China's casting industry is seen in northern iron-casting, where small iron objects such as harness elements were mass-produced in stack moulds. In this system tiers of identical and interlocking ceramic moulds were set one above another in tall stacks, connected by central vertical sprues. Molten iron was poured into this central channel and the moulds filled rapidly with metal. Almost immediately the moulds were knocked away and the castings retrieved. In terms of clay-working the particular interest in this approach lies in the fact that the thousands of moulds needed for the process were often made by pressing loess into cast-iron master-moulds, using bran as a releasing agent.[83] The moulds were fired in wood-burning cross-draft kilns to at least 700°C, and experiments with a few of the thousands of moulds recovered from the Han dynasty iron-foundry site at Wen-hsien 溫縣 in Honan province suggest that they were probably used hot (*c.* 300°C) after being held at red heat for some hours. Very similar methods of stack casting were used to cast bronze coins in the Han dynasty, and through to the Chhing dynasty.[84] A refinement of this process involved replacing

[82] See Anon. (1988a), National Museum of Chinese History, p. 37.

[83] 'Analysis of vegetable debris at the kiln indicates that the metal masters were dusted with a fine bran before clay paste was packed into them and pounded down to acquire the negative impression. The bran facilitated the clean parting of the clay mould from the master.' Hua Jue-ming (1983), p. 108.

[84] Bowman *et al.* (1989), p. 25.

the single-use ceramic moulds with reusable cast-iron valve moulds, an approach applied to the casting of iron or bronze sickle-blades as early as the Warring States period.[85]

Bronze-Working Techniques Using Clay and Bronze Age Ceramics

The precise and finely detailed clay models made by Shang dynasty bronze-founders are obviously superior, both in form and finish, to the ceramic vessels made by Shang dynasty potters. This fact may seem odd at sites such as An-yang, where bronze-casters and pottery vessel-makers worked in such close association. The high status of bronze and its related styles may partly explain this difference. Even so, given their common origins in ceramic techniques, one might expect the few Shang dynasty whitewares that have been found at An-yang to be nearer in form and ornament to contemporary bronzes than they are. A possible reason for this disparity might be that the prime model-making tool for the bronze industry – the running profile – was effective only on solid clay models, and unsuitable for soft or leatherhard pottery vessels, which would have crumpled and collapsed from the drag of the profile's edge. It is less clear, however, why the use of concave ceramic moulds for creating ceramic vessels was so slow to be adopted in China. This does not appear to have happened until about the -6^{th} century, as exemplified by a cold-painted pottery vessel in the Institute for Archaeology and Cultural Assets of Shensi province 陝西省考古文物研究所.[86] This covered vessel from Shensi is 31 centimetres high, and other square-sectioned press-moulded vessels or cast-bronze forms, such as a covered *hu* found near Peking, and a similar vessel in the Victoria and Albert Museum, are as large or larger.[87]

One of the earliest texts to deal with ceramic manufacture was a section of *Chou Li* called *Khao Kung Chi* (The Artificers' Record), composed *c.* −500 to −450. Although the primary function of *Khao Kung Chi* was not that of a manual describing working practices, it did reflect the Eastern Chou dynasty official handicrafts industry in the Shantung region as early as the −5th century, and discussed the craft of pottery (thuan shih 摶埴) at some length.[88] In addition to specialised division of labour among potters, it also listed regulations concerning size, thickness and volume of ceramics and prohibition against selling damaged ware. It was a work much

[85] *The Genius of China* exhibition in London in +1973, included cast-iron moulds for both sickles and socketed axes, found in Hopei province and dated to the -5^{th} to -4^{th} centuries (exhibits 119 and 120). Watson (1973), p. 90, speculates on which metal was cast in these moulds, suggesting that bronze appears more likely than iron, having the lower melting-point, although he adds that the use of iron is rather indicated by neither of the object-types' being found in bronze. See Wagner (1999), pp. 1–9, for a recent overview of the early use of iron in China.

[86] Illustrated in Fahr-Becker (1999), p. 57.

[87] See Anon. (1988a), National Museum of Chinese History, p. 61, fig. 4–1–4, for an example with painted red designs. The vase in the Victoria and Albert Museum (accession no. C.628–1925) is 37 centimetres high.

[88] Wen Jen-Chün (1987), pp. 123–38.

quoted by later ceramic scholars. Chu Yen 朱琰 (+1774), for example, used it in a section of his own book concerned with the invention of pottery:[89]

In making pottery there were artisans who used the wheel (*thao-jen* 陶人) and those who used moulds (*fang-jen* 舫人). The potters who used the wheel made vessel forms *yen* 甗, *phen* 盆, *tseng* 甑, *li* 鬲 and *yü* 鬳. The potters who moulded made *kuei* 簋 and *tou* 豆 . . . when a piece was shaped on the wheel a model was put against it so it could be accurately made, while a plumb-line was suspended so that the stem of the *tou* would be upright.[90]

This method of defining the parameters of a vessel and keeping it level, echoes the use of the rigid "running profile" for making the solid clay models for bronzes, described above. By the late Eastern Chou dynasty period, incidental text references confirm such measuring techniques. *Chuang Tzu* (The Book of Master Chuang, *c.*–290), for example, mentions a potter describing how to make good ceramics using a compass for round vessels and a carpenter's square for square ones.[91] The degree of accuracy implied is borne out by the regular appearance of many Chou dynasty ceramic vessels.

Chu Yen says that the articles made on the wheel were all cooking vessels except the *yü* 鬳 which was for measuring, while the moulded vessels were for sacrificial use. Contemporary research, based on archaeological evidence, suggests that the difference between the two groups of potters were that *thao-jen* made coarse ware and *fang-jen* made fine ware, rather than that one group threw and the other moulded as Chu Yen suggested. However, the difference between vessels made for ceremony and those made for domestic use was also the difference between fine and coarse wares, so Chu's interpretation has some validity.[92]

By the Chhin and Han dynasties numerous square-sectioned ceramic wares like those described in *Chuang Tzu* were being made for tombs, often decorated with painted designs, and apparently intended to imitate lacquer. Similar square-sectioned *fang-i* 方彝 are known in stoneware from south China, sometimes with greenish ash-glazes on their shoulders.[93] These are the fore-runners of the countless moulded flat-sided vessels made in stoneware and porcelain at such major sites as Lung-chhüan, Ching-te-chen and Hang-chou in the +13th and +14th centuries, and right through to modern times. In the Southern Sung and Yuan dynasties, a trend towards archaism seems to have encouraged the use of these model- and

[89] *Thao Shuo*, ch. 2, pp. 2a–b.

[90] Bushell's (1910) translation (p. 33) interprets the text in a similar manner. There had been some debate about the meaning of the phrase *chhi chung chuan, tou chung hsien* 器中膞, 豆中懸. Cheng Hsüan 鄭玄 (Eastern Han, +127–200) believed that the *chuan* 膞 was a rectangular plank used as an angle-measure to the *tou* 豆 vessel on the wheel, with rope suspended as a plumb line to keep the handle attachment straight: 'a plumb line was suspended so the stem of the *tou* would be upright'. Size was important, because any vessel with walls thicker than the regulated size would not fire evenly and would thus affect the quality of the finished ware. This explanation may be accurate or may reflect practices current in the Eastern Han, rather than those of the Eastern Chou dynasty period. Cf. *Chou Li Chu I*, ch. 41, p. 18; Wen Jen-Chün (1987), pp. 96–9. Sung dynasty scholars believed that the *chuan* was a type of special wheel, cf. *Hsien Chai Khao Kung Chi Chieh*, p. 26b.

[91] *Chuang Tzu, Wai Phien* ('*Ma Ti* '), no. 9. Cf. Wen Jen-Chün (1987), p. 97.

[92] Wang Chhing-Cheng (1982), pp. 188–9.

[93] An example from a private collection in Japan is shown in Satō (1981), p. 22, fig. 26.

mould-making techniques – particularly for production of some Kuan wares, Lung-chhüan celadons and Ching-te-chen blue-and-white porcelain.

Architectural Ceramics: Bricks and Tiles

While moulded vessels made from ceramic were rather late to appear in China, moulding had already been used for centuries in the country for making pipes, bricks and bricks and tiles (see pp. 104–15). The beginnings for this 'heavy clay' industry can be seen at late Neolithic Lung-shan culture sites in eastern Honan province, where fired drainage pipes have been excavated. In northern Honan province, during this same Neolithic period, the concept of 'modular' units for constructing buildings saw early use in China, when regular unfired clay slabs were used for house building.[94] However, early architectural ceramics were hand-built rather than moulded.

The hand building of architectural ceramics developed during the Western Chou dynasty when building products were made for the rulers. The seat of Chou dynasty power was in the central plain of Shensi province, over 100 kilometres west of Sian, and was first settled by the Chou in the reign of Thai Wang 太王 before the dynasty was established. There, in the area of modern Chao-chia-thai-tshun 趙家台村, were manufactured large, hollow bricks and smaller, solid bricks. They were composed of coarse, loessic clay bodies and were precisely made and strong. They were hand-built, and unlike later, Han dynasty, slab-built tiles, the large Chou dynasty hollow bricks were coiled.

Large hollow bricks were employed for steps, while strip bricks were utilised as wall and floor cladding. Archaeologists suggest that these were novel products in the early Western Chou period, and could only have been included sparingly in the most important buildings. By the late Western Chou dynasty a third type of fired brick appeared, that was used as cladding on the top of mud walls but not on floors, and called 'four nail bricks' (*ssu ting chuan* 四釘磚). All three types of brick were commonplace by the Warring States period, and have been excavated at many sites.[95]

Tiles

The pioneering technique of using baked clay tiles as roofing materials appears to have started in the Western Chou dynasty (*c.* -9^{th} to -7^{th} centuries, see p. 112). In +1961–62, a quantity of large tile fragments was discovered in the vicinity of Khun-ming

[94] Vainker (1991), p. 23. The Lung-shan culture site at Phing-liang-thai 平糧台, Huai-yang 淮陽, in Honan province is also claimed as China's first town to be surrounded by a wall of beaten loess.
[95] Liu Chün-She (1993), pp. 84–9.



Fig. 109 Chou dynasty tiles in the Chou-yüan Museum



Fig. 110 Chou dynasty tiles in the Chou-yüan Museum

lake 昆明湖 at Chhang-an 長安. Archaeologists had concentrated their search for a Chou dynasty capital (Feng 豐) in this area because of numerous references in early texts.[96] In addition to a wealth of impressed and cord-marked vessel sherds, debris from the interior of an ancient well contributed about 1,500 kilograms of ceramic tile fragments. One huge, semi-cylindrical, complete tile alone weighed 4.75 kilograms, so the archaeologists reckoned to have unearthed the equivalent of 300 tiles, enough to roof a very large building or buildings.[97] The complete tile had a loop on top towards one end, a feature repeated on a mass of tiles excavated in the Chou-yüan area. Tiles exhibited in the Chou-yüan museum resemble those in the Chhang-an excavation report, being large, heavy and semi-cylindrical in section.

This form is supposed to have been adapted from the shape of bamboo canes split lengthways, bamboo probably having been employed for roof covering, water conduits and gutters.[98] The tiles were made of coarse grey earthenware, were formed in moulds, and had rough striations on the exterior. Also on their exterior, either near the ends or in the middle, were ceramic loops. Corresponding tiles had protruding ceramic knobs, the two features (loops and knobs) forming an efficient mechanism for fixing tiles together when hanging them on a pitched roof.

Even more elaborate were semi-cylindrical pipe tiles from Chou-yüan, whose solid eaves' ends were patterned with elaborate moulded designs taken from the bronze repertoire. Comparison of the patterned ridge tiles with contemporary bronze design reinforces the radiocarbon dating of the site to the early Western Chou period.

During the Eastern Chou dynasty the forms of tiles evolved to include cylindrical, pipe-shaped tiles (with holes bored through at the end to aid firing); flatter tiles with only a slight convex curve; semi-cylindrical tiles; and semi-cylindrical tiles with a flanged end.[99] The latter feature allowed tiles to be slotted into one another end-to-end, a new method of fixing. Tiles tended to be smaller but still unglazed, typical measurements of the flat type at a Warring States site being 46 × 23 centimetres. The large mass of tiles at Warring States sites (also in the Chou-yüan area, in the counties of Fu-feng 扶風 and Chhi-shan 崎山) included tiles other than ridge tiles with complex surface designs derived from bronze.[100]

[96] Clues were given in *Shih Chi* (Western Han, about −90) in the chapters on Chou dynasty and Shih-Huang-Ti, First Emperor of the Chhin 秦始皇帝; in the section on geography in *Chhien Han Shu* (Eastern Han, about +100); in the section on the Wei river in *Shui Ching Chu* (late +5th / early +6th century); and in ch. 25 of *Thai Phing Huan Yü Chi* (Sung, about +980). See Anon. (1963a), p. 412. Khun-ming lake (so named when Emperor Wu of the Western Han 漢武帝 commenced major works there) was part of the Western Chou dynasty city of Feng, used for imperial ancestral temples and pleasure parks. The lake was a resort during both Han and Thang dynasties. See Zou Zongxu (1987), pp. 68, 73, 285.

[97] Anon. (1963a), p. 408.

[98] Hommel (1937), pp. 257–8; Needham & Wang (1965), p. 134.

[99] See Anon. (1960b), p. 12, pl. 11.

[100] Anon. (1963b), p. 655.

It was in the Warring States period that lead-glazing of earthenwares first commenced.[101] However, during the late Chou dynasty to Han dynasties lead glazes seem only to have been used on vessels and figurines, most if not all of them intended for burial. Roof tiles and other decorative tilework appear to have remained unglazed.[102] At present, archaeological and textual research indicate that it was the Northern Wei dynasty that first saw the appearance of lead-glazed tilework.[103] It is interesting that Wei dynasty territory encompassed sections of both Shansi and Honan, and these northern provinces have continued as major centres for tilework to the present day.[104]

Architectural Ceramics in the Chhin Dynasty

Many ceramic tiles and slabs were found in the region of Chhin dynasty power in Shensi province, and especially at the palace sites in Hsien-yang 咸陽. They were all made of grey loessic clay, formed by slab moulding, and with moulded and carved surface decorations. The most striking components were large, flat, hollow ceramic slabs with elaborate, carved dragon and phoenix patterns, used to line walls in palaces and tombs. Measuring about 1 to 1.5 metres in length, by about 40 centimetres in width and up to 18 centimetres in total thickness, their construction represented a considerable feat for the potters of the time. The slabs' hollow nature aided making and drying, and firing in the kiln, and also insulated buildings against sound, damp and loss of heat.[105]

At several Hsien-yang palace halls, and at the First Emperor's tomb, were found other ceramic building materials. Smaller, solid ceramic slabs were common, with several different types of pattern. Bricks with sun and flower patterns ($44 \times 37.5 \times 4$ centimetres and $38 \times 38 \times 3$ centimetres) occurred alongside completely plain bricks, or slabs with simple textile and ridged patterns.

This architectural pottery included a feature found also on later tiles (see pp. 498–9 below), namely the application of stamped characters. More than 80 types of inscription have been deciphered, some the surnames of potters, others indicating the context of use or the hierarchy controlling manufacture.[106]

The government bureaux controlling brick- and tile-making during both Chhin and Han dynasties were called *Tu Ssu-khung* 都司空, *Tso Ssu-khung* 左司空, *Yu Ssu-khung*

[101] Wood & Freestone (1995), pp. 12–17. A +1960 archaeological report, Anon. (1960c), proposed a find of Spring and Autumn period glazed earthenwares at Hou-ma in Shansi province, but the authors have discovered no substantiation for the dating of the artefacts.

[102] For example, a large number of tiles was excavated during the +1970s from the site of the capital city of the state of Chao 趙國. This Warring States city, in the environs of present-day Han-tan city 邯鄲市 in Hopei province, was an important economic centre whose prosperity was indicated by a wealth of finds. The tiles unearthed were unglazed grey ceramic, with moulded designs. Cf. Chang Chün-Ying (1995), pp. 79–91.

[103] *Thai Phing Yü Lan* (+983) noted the use of glazed tiles in later Wei, see Feng Hsien-Ming *et al.* (1982), pp. 175–6.

[104] Krahl (1991), p. 48.

[105] Early use of large hollow ceramic slabs included Warring States burials at Erh-li-kang, their average size being $107 \times 30.5 \times 15$ centimetres. See also Needham *et al.* (1971), pp. 38–57, in particular p. 40, note i.

[106] Anon. (1976a), pp. 23–4; Chao Khang-Min (1979), p. 16; Vainker (1991), p. 44.



Fig. 111 Remains of hollow ceramic slab with carved phoenix pattern from Hsien-yang palace

右司空 and *Ta-chiang* 大匠,[107] though several additional but unidentified offices were named on Chhin dynasty artefacts. It is clear that new offices were established as building demands increased, and that a shortage of skilled workers led to the training of army convicts and slave conscripts.[108]

Chhin dynasty roof tiles comprised cylindrical pipe tiles, flat tiles with slight convexity, and a range of patterned end tiles. The largest tile-end found in China to date came from near the First Emperor's tumulus. Measuring 48.5 × 61 centimetres, it was decorated with intricately stylised dragons.

Unusual patterns on the smaller, round tile-ends included a leopard (it was suggested inspired by exotic animals kept in the imperial hunting park), deer, tiger, rooster and character inscriptions. The longest inscription came from a tile found at his

[107] All of these bureaux supervised the manufacture of bricks and tiles. *Tu Ssu-khung Yü* 都司空獄 was a prison for imperial kinsmen during the Han period, a jail at the dynastic capital under the Chief Director of Convict Labour (*Tu Ssu-khung Ling* 都司空令). This official supervised convicted criminals (members of the imperial clan in the first instance) who were assigned to labour projects in the capital. *Tso/Yu Ssu-khung* came under the Chamberlain for Palace Revenues (*Shao-fu* 少府), an important post in central government. *Ta-chiang*, that became *Chiang-tso Ta-chiang* 將作大匠 (Chamberlain for Palace Buildings) in the Western Han dynasty, was responsible for construction and maintenance. Hucker (1985), pp. 140–1, 414–15, 540, 542. Yüan Chung-I & Chheng Hsüeh-Hua (1980), p. 83.

[108] Yüan Chung-I & Chheng Hsüeh-Hua (1980), pp. 83–92; Wang Zhongshu (1982), pp. 149–50.

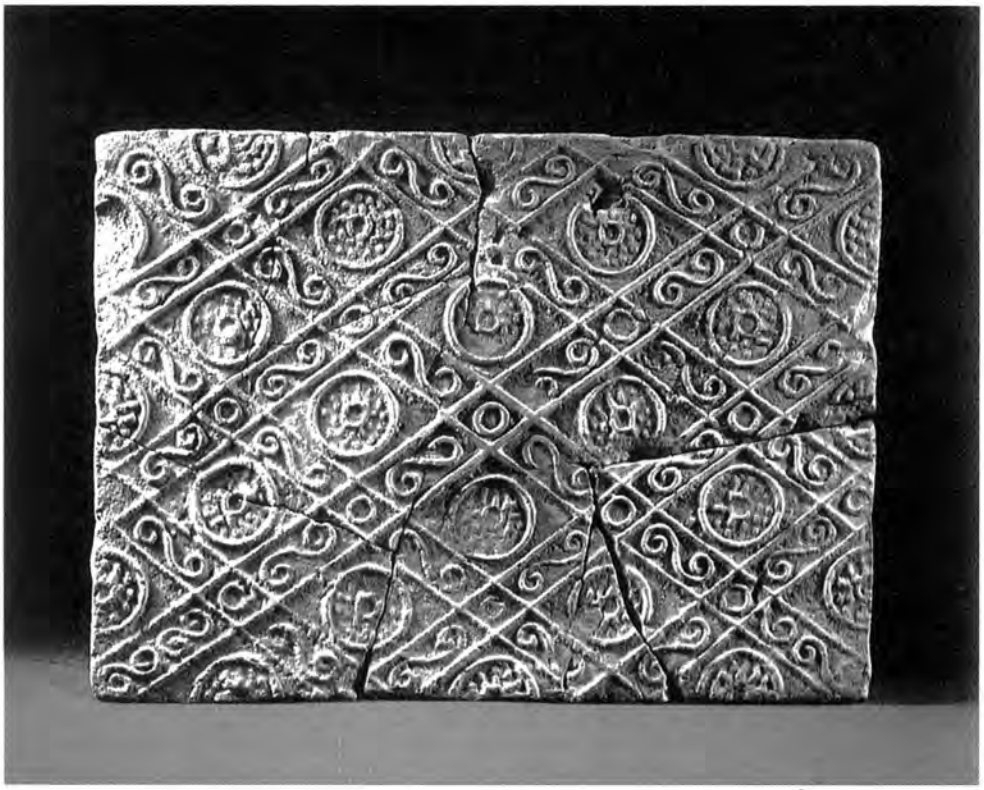


Fig. 112 Solid floor brick with floral pattern from Hsien-yang palace

A-fang palace 阿房宮 site (Fig. 116).[109] Material from this site, including large, grey paving-tiles, bricks, drainage pipes and ceramic cisterns, is displayed at the Hsien-yang Museum. The inscribed tile bore twelve characters that read:

The Spirit descends from Heaven, so that the court will endure for 10,000 years, and there will be peace and tranquillity on earth below.

Unhappily, the short and bloody dynasty of Chhin (–221 to –207) did not requite this pious wish.[110]

[109] Construction of the huge A-fang palace at Hsien-yang started in –212. *Shih Chi*, ch. 6 ('*Chhin-Shih-Huang*'), p. 17b states that: 'From east to west it was five hundred paces, from north to south fifty feet, 10,00 people could be seated in the upper floor, while below could be erected banners fifty feet in height … A labour force of more than 700,000 – men punished by castration or sentenced to penal servitude – was drafted to build A-fang Palace and the emperor's mausoleum on Mount Li 驪山. Stone was quarried from the northern hills, timber shipped from Shu 蜀 and Chhu 楚. Three hundred palaces were built within the Pass, and east of it more than four hundred.' See Yang Hsien-Yi & Gladys Yang (1974), pp. 178–9.

[110] For the Chhin excavations and architectural ceramics see: Anon. (1976a), pp. 18–21, pls. 1–3; Anon. (1976b), pp. 42–4; Zou Zongxu (1987), pp. 68–9, 76–9, 169, 243.

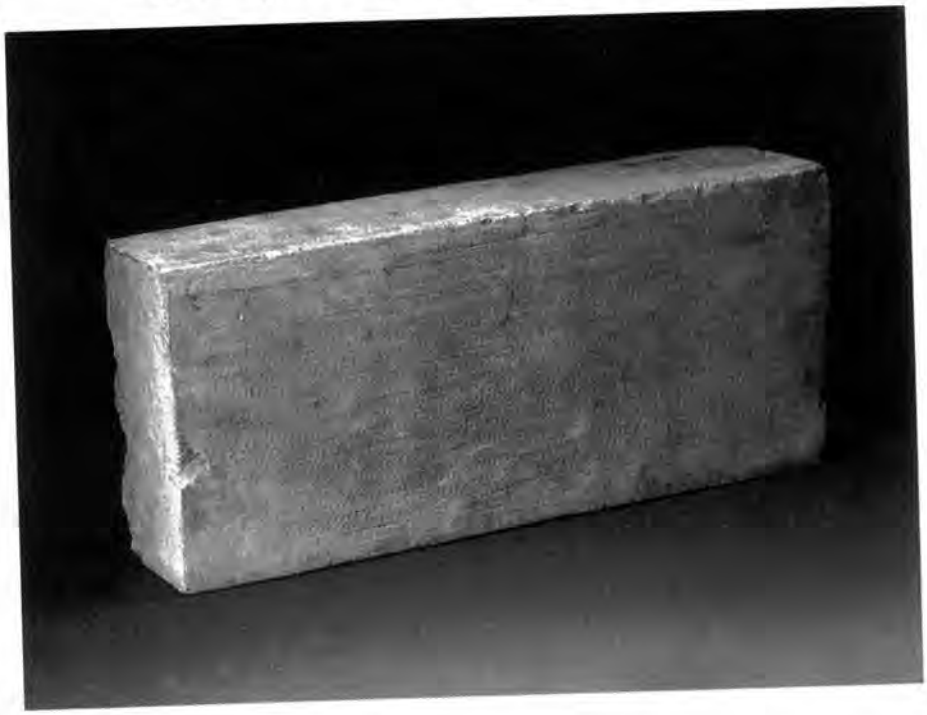


Fig. 113–114 Rectangular ceramic brick from the First Emperor's tomb with stamped name *An Wei* 安未

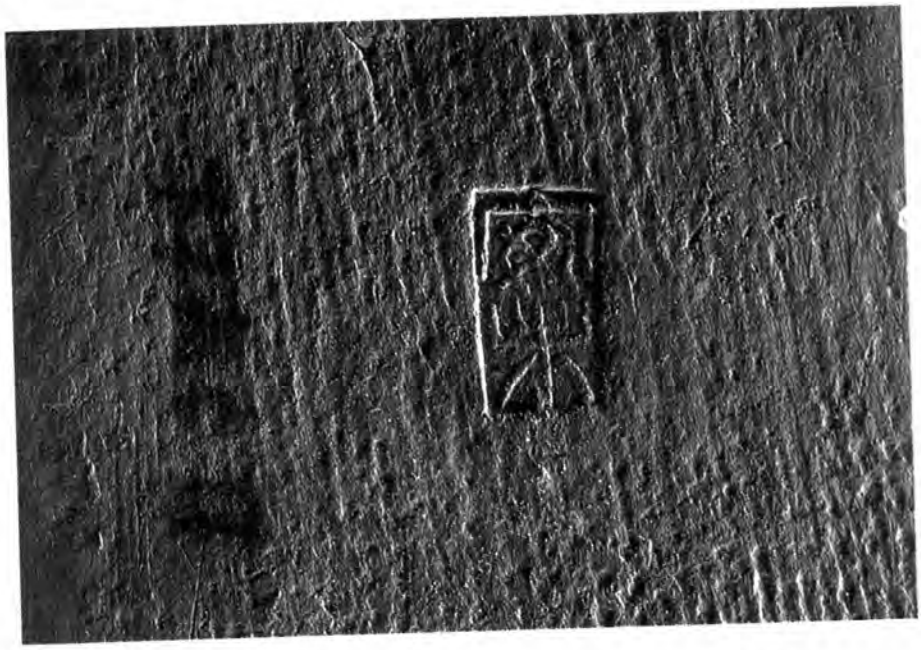


Fig. 114



Fig. 115 Large eaves tile from the First Emperor's mausoleum

It is relevant that many of the earliest developments in ceramic tiles and other architectural ceramics were made in northern central China, in the provinces of Honan, central Shensi and southern Shansi, heartland of Central Plains culture. Beginning in the Eastern Chou period, however, other areas also produced prodigious quantities of building materials. The capital city of the state of Chhi 齊, at Lin-tzu 臨淄 in Shantung province, was excavated in the early +1990s and yielded more than a hundred complete and fragmentary tiles dating to the Warring States period.[111] They comprised cylindrical and semi-cylindrical eaves tiles decorated with a variety of lively motifs that favoured animals, birds and reptiles with stylised tree motifs. Although the archaeological report does not include descriptive or technical description of body-material or manufacture, the tiles appear to be moulded and made of reduction-fired loessic clay.

The series of architectural sites known as Chiang-nü-fen 姜女墳,[112] situated in Liaoning province just outside the Great Wall, was excavated during +1984 and +1985. It was probably originally the site of one of the First Emperor's temporary palaces used when travelling, and yielded an area densely packed with a range of tiles. They included pipe tiles and decorated end tiles and one huge semicircular

[111] Chang Lung-Hai (1992), pp. 55–9, pl. 7.
[112] Meaning 'tomb of the ginger-woman', after the local name for rock formations just off the coast.



Fig. 116 Round end tile with character inscription from A-fang Palace

ceramic brick with bronze-like decoration that measured 52 × 37 centimetres and resembled that found near the First Emperor's tomb. There was also a large, flat, hollow slab with lozenge decoration measuring 60 × 47 centimetres, and a variety of tiles with stamped inscriptions.[113]

Architectural Ceramics in the Han Dynasty

A particular feature of Western to early Eastern Han tombs was their decoration using hollow ceramic slabs (see p. 114). The largest slabs interlocked to line the walls, and also served as lintels to surround doorways. The use of durable materials ensured that the tomb would survive beyond the lifetime of any members of the deceased's generation.[114] The size of the ceramic architectural components meant that they needed to be hollow for firing, and also that their body-material should be dense, fine and homogeneous. Conservation and research on three items of Han

[113] Anon. (1986d), pp. 25–40.
[114] Thorp (1987), p. 29.



Fig. 117 Chhin dynasty tile-ends from Shantung province

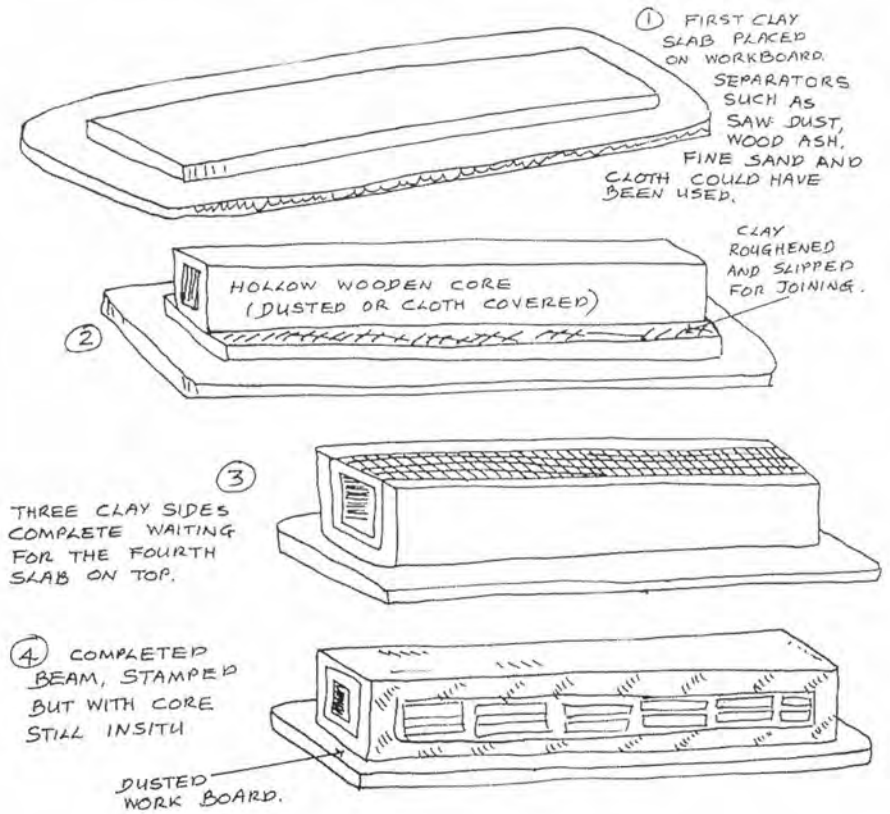


Fig. 118 Drawings to show Han dynasty hollow brick construction, suggested method one, by Anne Brodrick

dynasty architectural ceramics, two doorposts and a lintel, revealed some interesting facts about their construction and composition.[115]

The ceramic bricks are in the collection of the Victoria & Albert Museum, and information derived from them may be used as a standard for similar tomb architecture from the northern provinces of Shensi, Honan and Hopei. Each item is long, hollow, four-sided and open at both ends. Designs were stamped into the outer surfaces while the slabs were in the stiff-plastic state. Moderate pressure would have been needed to achieve this, and therefore interior support was required if the fabric was not to distort and crack from the pressure. The stamps would have needed to lift cleanly away from the stiff clay surface, and a dusting of fine sand,

[115] The three tiles were conserved and analysed in +1990–91, in the Conservation Department of the Victoria & Albert Museum, and at The Royal School of Mines at Imperial College, as part of a programme to prepare objects for display in the T.T. Tsui Gallery of Chinese Art at the V&A. See Kerr *et al.* (1991), pp. 399–414, and Brodrick *et al.* (1992), pp. 118–28.

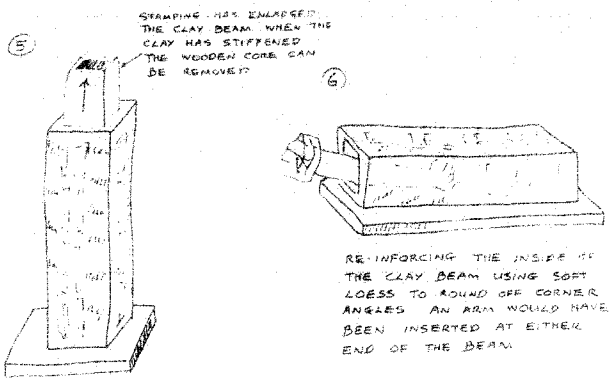


Fig. 119 Drawings to show Han dynasty hollow brick construction, suggested method one, by Anne Brodrick

wood ash or sawdust would have assisted this process. Two possible methods of construction were proposed, to take into account all these features, observed through visual and microscopic examination (though several more options for construction are possible).

In method one, clay was beaten and/or rolled out to a uniform thickness on a board and either cut to size, or prepared between parallel wooden guides. A separator, in the form of cloth or some suitable dust, would have been necessary to stop the clay from sticking to the board beneath. A square-section wooden core was then placed on the clay slab. This could have been a simple, long, hollow wooden box made from sawn boards. The three remaining sides of the beam could then have been added from similar pre-formed clay slabs with the edges roughened and stuck with clay slip. Once the hollow beam was fully assembled, the decoration of the beam could have been stamped, with the wooden core in place to support the form. The wooden core would need to be removed before the beam began to shrink. This could have been managed by up-ending the beam, using long boards to support the shape, and simply pulling the wooden core out. When the wood core had been removed the internal clay walls would have been reinforced on the internal angles with more clay giving the characteristic cross-section found on the bricks. This would have given added strength and also discouraged cracking along the joins. An arm inserted at either end of the brick would give overall access to the internal corners of the whole length of the brick, and it may be that this two-arm-span length

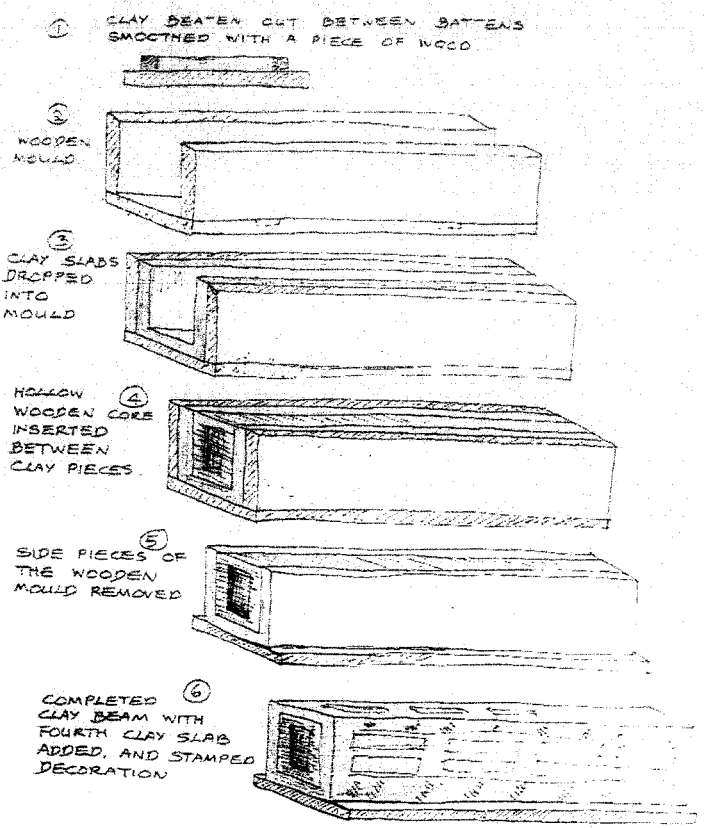


Fig. 120 Drawing to show Han dynasty hollow brick construction, suggested method two, by Anne Brodrick

was a standard for such structures. After internal reinforcement the end-pieces (pre-formed roughly to size) would have been applied and trimmed.

Method two differs from method one in that the pre-formed slabs would have been assembled inside a U-shaped wooden mould. When the U-shape was complete in clay a wooden-box former, identical to that used in method one, would have been placed inside. The top slab would have then been set in place, with the usual roughing and slipping needed when clay edges are stuck together in making. The two upright boards of the U-shaped former could then have been removed and the beam stamped with the inner wooden box still *in situ*. After a short drying period



Fig. 121 Illustration from *Thien Kung Khai Wu* (+1637) to show brick-making

the beam could have been stood on end and the inner box drawn out. Stamping the completed brick seems likely as it would have been extremely difficult to pre-stamp the slabs, and then assemble them, without seriously damaging the patterns in the joining process. Strengthening of the internal angles with extra sticky clay and the addition of end-pieces would have been the same as method one.



Fig 122 Illustration from *Thien Kung Khai Wu* (+1637) to show water being used for reduction-firing

The tomb doorposts and lintel were made of loessic clay, fired to the region of 1,000°C, and then reduced or reduction-cooled.

The manufacture of another important product from the early Western Han dynasty, i.e. small, solid bricks, is an activity that probably changed little over centuries. *Thien Kung Khai Wu* (The Exploitation of the Works of Nature, +1637) described processes in a manner that was augmented by Rudolf Hommel (+1930s)



Fig. 123 Illustration from *Thien Kung Khai Wu* (+1637) to show a coal-briquette-burning clamp kiln

and Ronald Knapp (+1980s).[116] All three contained accounts that should have been familiar to a Han dynasty brick-maker. Clays were selected from river or canal banks, or irrigated fields whose surface needed to be lowered. Clay from such locations would have already been refined through the action of water, the particles

[116] *Thien Kung Khai Wu*, ch. 7, pp. 2b–3b. Sun & Sun (1966), pp. 137–44. Hommel (1937), pp. 259–70. Knapp (1986), pp. 60–2.



Fig. 124 Brick-making at I-chhang 宜昌 by the Yangtze river, +1935

sorted by size and texture. The clay was moistened with water and kneaded by foot[117] in a pit, before being moulded in wooden moulds using ash as a separator. Excess clay was trimmed from the moulds with a wire cutting bow, the bricks were air-dried for about a week and then fired in kilns that burned brushwood or coal, as available. The kilns were buttressed into the earth for insulation, with a central opening in the top. This hole was sealed after the kiln was filled with bricks, leaving only observation and draft holes in the sides.

The remains of an Eastern Han dynasty tile kiln excavated on the site of the ruins of the Han and Wei dynasty city at Lo-yang 洛陽 in Honan province gave a fairly clear picture of its structure.[118] The kiln was dug into the ground, 6.7 metres long, 2.7 metres wide and with a chimney at the back, and was fired by coal.

THE TERRA-COTTA WARRIORS

As the preceding pages demonstrate, a great fund of technical expertise in the handling and firing of loess had accumulated in two quite separate northern Bronze Age industries; firstly in the yards making bricks and tiles, and secondly in the

[117] Either human feet, or oxen/water buffalo.

[118] Anon. (1997a), pp. 47–51. A number of such kilns have been found scattered over a wide area, confirming the theory that kilns for architectural ceramics were set up wherever large-scale building was to be carried out. See also Figs. 66, 67 and 69 of this volume.

mould-making shops of the bronze and iron foundries. In brick- and tile-making the fired-strength and the good drying and firing behaviour of the material were thoroughly exploited. Metal-casters appreciated loess's capacity for low shrinkage, its ability to take fine detail from models, and its porosity to absorbed gases in molten metal.

In the early –3rd century, these two traditions in the manipulation and firing of loess (large-scale brick-making and advanced mould-making) were combined to create one of the world's most extraordinary ceramic productions. This was the underground terra-cotta army installed near to the tomb of Shih-Huang-Ti, First Emperor of the Chhin 秦始皇帝. The life-size army, containing more than 7,000 armed warriors, and hundreds of horse-drawn chariots, was placed to the east of the vast tumulus covering the First Emperor's tomb, in Lin-thung county 臨潼縣, some 30 kilometres east of Sian in Shensi province.[119]

The manufacture of the terra-cotta warriors combined mass-production with hand finishing. The warriors were made from loess, and the raw material was press-moulded into large porous moulds. These realistically painted figures, holding real weapons, were set in full battle order on lanes of grey brick, in deep trenches cut into the local loessic soil. The trenches were spanned with heavy timber roofs, supported by wooden pillars, and the roofs were protected with a combination of woven matting and plaster. The whole structure was then covered with a deep layer of loess. Two farmers discovered the site in +1974 when they were digging a well. As the first large pit of figures was excavated (Pit One) most figures were seen to have been broken and their paintwork burned away. Apparently the whole structure caught fire at the time that the Chhin dynasty was overthrown (–206).[120]

Exhibition catalogues and descriptions of the site have tended to emphasise the realism of the figures, and the manner in which they appear to replicate elite battalions from the First Emperor's army. Several scholars, however, have emphasised that the army was never intended as portraiture, rather that its verisimilitude was necessary for practical religious reasons, to guard its master in the nether world.[121]

CONSTRUCTING THE TERRA-COTTA WARRIORS

In terms of practical production, the terra-cotta warriors were made as a number of sections, designed to be assembled after firing, namely combined leg and waists, torsos with arms, hands and heads. Hands and heads were made with hollow 'spares' attached, intended for fitting into the hollow torsos. The heads simply rested in place, while the hands were secured with pegs.

[119] 'From a geomantic point of view the tomb occupies a propitious 'lotus nut' location, hemmed in by the 'lotus-petal' peaks of the Li-shan mountains.' Wang Hsüeh-Li (1994), p. 7. Further finds at the site have been reported recently, particularly a group of life-sized pottery figures of bare-chested acrobats, one of whom had a green-painted face.

[120] Capon (1983), pp. 42–3.

[121] Clunas (1997), pp. 30–2; Rawson (1998), p. 34; Ledderose (2000), pp. 52–5.

Study of the broken and dismantled figures at Lin-thung has shown that fine loess had been pressed and smeared into hollow porous moulds. The larger sections were then reinforced inside with thick ropes of loess, pressed and beaten against the initial moulding to give a wall thickness of about 5–10 centimetres.[122] The small shrinkage associated with the drying of loess was enough to separate the pressings cleanly from their moulds. Once removed, the pressed sections were improved by hand finishing and by the addition of moulded details, such as armour for the bodies, and noses and ears for the heads.

This soft-pressing technique is still used in England for making large architectural terra-cotta units in porous moulds.[123] By using slightly more water than is usual in clay-water mixes, the material can be easily smeared inside the moulds. Clay used in this soft state presents little resistance to its distortion in the pressing process, and this lessens its tendency to crack during drying from the phenomenon of 'plastic memory', i.e. the capacity of a distorted clay mass partially to regain its original form. Clays with a high component of non-plastic materials such as loess also need very little water to bring them to a soft-plastic state (*c.* 14% by weight with loess compared with 20%+ for most clays),[124] so that shrinkage from excessive water of plasticity does not present a problem. Evidence of soft-pressing can be seen on the inside surfaces of some broken warriors. A recent study of these figures remarked that they are 'almost free from flaws of distortion or cracking . . .', which is a most remarkable feature in such large ceramic objects.[125]

A standing human figure is unstable, so although the figures are essentially naturalistic their balance was improved by making the legs solid, by attaching each figure to a solid ceramic slab about 34 centimetres × 34 centimetres square, and 3.5–4 centimetres thick, and by using thicker pressings of clay at the fronts of the torsos.[126] In most cases the foot plate was fixed to the legs during making and firing, but in a few cases the attachment is post-firing, using a cement made from loess and lacquer.[127]

The concept of mass-production with personalised details was effective and efficient. For example, only two types of feet were used, one with square-toed shoes and the other with central-lacing boots. Right and left feet were made from the same moulds. Likewise, only two types of hands were employed, one with extended fingers and the other with the fingers half closed, as if grasping a pike, although in this case right and left versions were made.[128] Heads were constructed in two vertical parts in open press-moulds (face and head-back), without ears or noses, and then joined. Ears and noses were press-moulded separately and attached with slip.

[122] H. J. Qu *et al.* (1991), p. 4. The presence of these reinforcing coils led some writers to suggest that the warriors were entirely hand-built, for example see Wiedemann *et al.* (1988), p. 129.
[123] Author's (NW's) observation at Ibstock Hathenware Ltd., UK, +1997.
[124] Author's (NW's) experiments with loess, +1992.
[125] Qin Guangyong *et al.* (1989), p. 4.
[126] The kneeling crossbowmen are set on tiles 34 centimetres × 16 centimetres, probably halved from the square slabs. H. J. Qu *et al.* (1991), p. 463.
[127] *Ibid.*, pp. 463–7.
[128] A few hands were modelled individually, such as those for the Generals.

Particular care was taken to make the features and the hair of the warriors individual, through a mixture of moulded and hand-modelled details.[129] The heads were interchangeable and, like the hands, were fired separately from the bodies. The armour was added to the plain moulded torsos as separate clay pieces, with some details (such as straps) being press-moulded, while others (such as individual armour plates) were hand-cut, with the four rivets on each plate applied separately.

The Horses

The life-size horses (height 1.5 metres, length 2 metres, with a finished weight of 225 kilograms each) presented a particular challenge in production.[130] Heads (without eyes or ears, but with upper mouth and teeth) were made in two-part moulds, with the moulded eyes and ears attached later, followed by the lower jaws. The necks were also pressed in two-part moulds, while massive two-part open moulds were employed for the horses' bodies, with the loess beaten into the separate mould sections with cloth-bound posts. After joining the two body halves together, round holes 10–11 centimetres in diameter beneath the horses' bellies were used to give access to the craftsmen's arms, for finishing and compacting the inner joints. The solid moulded legs were then inserted into holes left in the horses' body, and again sealed thoroughly inside, via access from the bellies, which were pressed much thicker (*c.* seven centimetres) than the backs (*c.* three centimetres). Once the legs were in place the horses were finished with moulded tails. As so 'much of the structural detail became rounded and lost during handling and joining'[131] the whole horse was then covered with about a 0.3–1.5 centimetres coat of clay. This was smoothed and polished, then enhanced with crisp carving, to emphasise the features of the heads, manes and muscles of the legs. Chinese investigators summarise the process thus:[132]

> The manufacture of the terra-cotta soldiers is a very complex process, involving making several separate parts and joining each slowly, and in a very special order. Molds have been used for the large parts, after which the sections are decorated. Therefore the soldiers were formed from both molds and handwork. The special sequences of manufacturing steps for each individual type of soldier involved a complex organisation of craftsman who were specialized in particular tasks and who were aware of the subtle difficulties which may have caused a figure in the later part of the processing to have cracked, warped or broken.

Once constructed, the warriors were dried and then fired to temperatures in the region of 800°–1,000°C.[133] The firing was initially in oxidation, but the kilns

[129] For example, 24 categories of moustaches and beards have been counted.

[130] This may seem small for a horse, but contemporary skeletons of horses found at the same site are of this general scale. Elisseeff & Elisseeff (1983), pp. 113–14.

[131] H. J. Qu *et al.* (1991), p. 475.

[132] *Ibid.*, p. 473.

[133] *Ibid.*, p. 460. One figure examined is believed to have been fired to about 940°C and a horse to about 805°C.

changed to reduction for the later firing and early cooling.[134] The average weight for a fully assembled and painted figure (plus base plate) was about 110 kilograms, and for a horse about 225 kilograms. With more than 7,250 figures and some 40 horses, together with the brick paving on which they stood, this represents the moulding and firing of about 11,000 metric tonnes of plastic loess.[135] Although no kilns have yet been found for firing the warriors and horses, the large cross-draught 'cave kilns' used by Chhin dynasty brick- and tile-makers might possibly have served the purpose.[136] The terra-cotta army presents an ongoing archaeological and technological puzzle that will continue to unfold as more studies are conducted.

[134] Qin Guangyong *et al.* (1989), p. 6.

[135] H. J. Qu *et al.* (1991) give the tally as follows: Pit One 6,000 warriors and 24 horses. Pit Two 1,117 warriors and 'some horses'. Pit Three 68 warriors and 4 horses. By contrast Capon (1983), pp. 33–43, gives 6,000 warriors and 120 horses for Pit One, 1,400 figures and 256 horses for Pit Two, and 68 warriors and four horses for Pit Three. Anon. (1994), Shaanxi Historical Relics Bureau, p. 4, gives the number of rectangular paving bricks beneath the warriors as 230,350, with a typical brick measuring 42 centimetres × 18.2 centimetres × 9.5 centimetres. However, this quantity of processed loess (*c.* 11,000 tonnes) should be considered in relation to the 50 million tonnes of rammed loess used to make the First Emperor's tomb mound, with its original height of 116 metres and its circumference of 2,087 metres.

[136] Wang Hsüeh-Li (1994), pp. 1–2, states: 'The east of the mausoleum area was occupied by pits of terra-cotta warriors and horses, as well as of stables. To the west of the area of accompanying tombs was the place for the baking of bricks and tiles and for the processing of tomb materials, as well as the graves of the tomb builders.'

LATER CERAMIC-MAKING TECHNIQUES

LATER MANUFACTURING PROCESSES AND SEQUENCES IN CHINA

It is a curious fact that some of the most advanced making techniques used for ceramics in China saw little general exposure in their time. For example, Shang dynasty bronze-casting moulds were broken and discarded after use, and the life-sized Chhin dynasty terra-cotta warriors at Li-shan were deliberately and completely buried. Nonetheless these constructional triumphs of the late Neolithic period, and Bronze and Iron Ages, still stand as the most significant practical successes of clay workers in China. After the late Bronze Age, relatively few new methods for making ceramics were introduced or developed. Those that were, tended to appear in the +10th and +11th centuries, particularly from the influence of silver on ceramics. Some of these new techniques were designed to unite the processes of throwing with moulding, and the main advances in this area occurred at the Yao-chou and Ting ware 定窯 workshops in north China.

YAO-CHOU 耀州窯

The Huang-pao 黃堡 site, near the city of Thung-chhuan 銅川 in Shensi province, is celebrated for the quality of its celadon wares, particularly those made from the +10th to the +12th centuries, when they were known as 'Yao-chou wares' in China (see also p. 165). Glazed stonewares were first made in the area in the mid Thang dynasty, and continued production there until the early Ming dynasty. They were fired first with wood and then, from about the +11th century, with coal. The site has also yielded Neolithic wares from the Yang-shao culture, and the Huang-pao kilns were important suppliers of lead-glazed *san-tshai* 三彩 wares during the High Thang period, presumably for the Chhang-an funerary market. With the decline of the Yao-chou celadon industry in the Yuan dynasty, production reverted largely to blackwares and to white-slipped stonewares. Such ceramics had already seen production at Huang-pao during its formative years in the +8th and +9th centuries, and they continue to the present day, mainly for local consumption.

Numerous seasons of excavation have rendered the Yao-chou kiln-complex one of China's better-studied ceramic centres, comparable to those of Kuan-thai 觀台, Ching-te-chen 景德鎭, Lao-hu-tung 老虎洞 and Lung-chhüan 龍泉. Kilns, workshops, glazes, bodies and manufacturing processes have all been examined here in detail, with the development of Huang-pao moulds being particularly well documented.

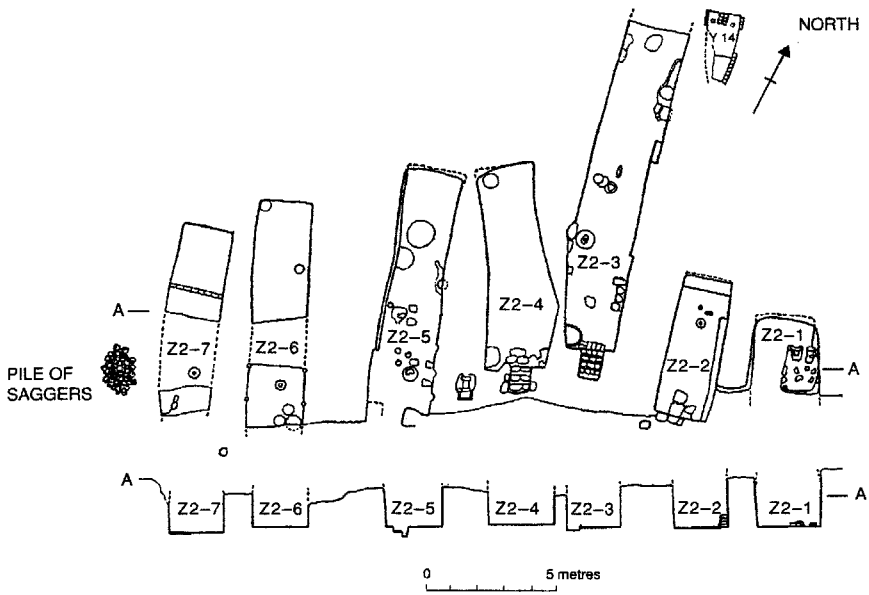


Fig. 125 Thang dynasty Yao-chou workshops at Huang-Pao

THANG DYNASTY MANUFACTURE

Excavation of the Thang site at Huang-pao in Thung-chhuan by Cho Chen-Hsi 禚振西 and Tu Pao-Jen 杜葆仁 between +1984 and +1990, unearthed many kilns. They included one workshop and three kilns for *san-tshai* wares, eight workshops and five kilns for high-fired wares, and seven ash-pits. The *san-tshai* workshops consisted of seven caves dug into the loessic cliffs along rivers. One was a dwelling for craftsmen and watchmen; another was for drying green-fired wares and applying glaze; a third housed a wheel, moulds and a working platform; a fourth was solely devoted to moulding; a fifth housed a wheel and clay vats and made only lamps; while the sixth and seventh caves had wheels and concentrated on vases and ewers. The workshops for high-fired wares (some caves and some open-air structures) were arranged in a different manner, according to manufacturing process. Thus there were sites for throwing and moulding, sites for glazing complete with glaze vats, and other areas for storing clay and fuel. The evidence from these two types of workshop making different wares, shows that labour was organised according to product category in the *san-tshai* workshops and according to potters' skills in the high-fired ceramic workshops.[137] The latter division of labour was the more usual at kilns in China.

[137] Anon. (1992a), vol. 1, pp. 10–19, 24–34, 530–3; vol. 2, pls. 1–22.

Thang *san-tshai* wares were often made in the functional vessel-styles of the time, but enhanced with coloured lead glazes, rather than the plain high-fired glazes of stonewares and porcelains. But *san-tshai* production also included a significant eclectic element, which took its forms variously from bronze, gold, silver, stone, glass, bone and ivory originals. Some models were Chinese luxury objects, but others derived from India, the Near East, Central Asia, and from cultures north of the Great Wall. In addition to these varied artefacts, Thang dynasty *san-tshai* wares included a wealth of figurines, such as horses, mules, camels, oxen and pigs, together with acrobats, dancing girls, musicians, polo players, courtiers, mythical beasts and tomb guardians. These ranged in height from a few centimetres to well over a metre. In choosing to imitate so many non-ceramic objects, *san-tshai* potters had to develop constructional techniques that were flexible and inventive. Press-moulding, slab-building, sprigging and throwing were all applied separately and together to various ends. Nonetheless close study shows that all these methods had featured in some ways in the production of Western and Eastern Han figurines and tomb objects. The main difference at Huang-pao was that biscuit-fired stoneware clays were now used for making moulds, rather than the traditional fired-loess. Analysis suggests that Thang dynasty and +10th-century moulds found at Huang-pao were made from the local refractory clay ('*ni-chhih* 泥池' clay) alone, while later Northern Sung, Chin and Yuan moulds show compositions that suggest recipes nearer to *ni-chhih* clay 80% and quartz 20%.[138]

MOULDING AT HUANG-PAO IN THE FIVE DYNASTIES PERIOD

Amongst the finds of Five Dynasties moulds at Huang-pao were a number of thick high-fired moulds with central wells bearing patterns on their inside faces. The unglazed stoneware moulds were about 73 millimetres diameter overall and produced raw cups about 50 millimetres wide. Their thickness and weight are unusual, but may have supplied useful mass when placed on potters' wheels. Wang Fen 王芬 and Wang Lan-fang 王蘭芳 note the moulds 'appear yellow on the curved surface as if [they] had been daubed with some kind of demoulding agent' and suggest that they were originally mass-produced from convex master-moulds because of the lack of detail in many of the final products.[139]

The particular moulds excavated had been used to make cups, with surfaces like fine basketwork. Sixteen near-identical examples were found at Huang-pao, probably sufficient for the first mould to be emptied and reused after the sixteenth cup had been made. It may be that the clay was spread inside the moulds by throwing.[140]

[138] Guo Yanyi *et al.* (1995), p. 322.

[139] Wang Fen & Wang Lanfang (1995), p. 314.

[140] A cup of this design, with a typical Five Dynasties Huang-pao bluish celadon glaze, is illustrated in Anon. (1992c), n.p. It is matched with a fine cup-stand bearing a central boss of moulded lotus-leaf form. A similar and perhaps earlier example, this time in Hsing-type 邢窯 whiteware and 5.3 centimetres in diameter, has been found at Chhing-ho-hsien 清河縣 in Hopei province, see Watson (1984), p. 126, pl. 100. The design also appears in Thang *san-tshai* ware.

If this were the case it would have been by no means a novel approach in world ceramics. Throwing into moulds was a popular technique in Greece as early as the -5^{th} century, and became the basis for Athenian unglazed wares in the -3^{rd} century.[141] The huge volumes of *terra sigillata*, the fine everyday pottery in the Roman Empire, and made particularly from the -1^{st} to $+2^{nd}$ centuries, exploited very similar making-methods.[142]

Another Five Dynasties practice at Yao-chou was sprig moulding to create appliqué patterns for enhancing plain forms. The method probably had its roots in *san-tshai* production at Huang-pao during the Thang dynasty. Small sprigged details also occur on southern high-fired ceramics as early as the Spring and Autumn period (-5^{th} or -6^{th} centuries). The technique was used then on greenwares from Chekiang and Chiangsu provinces, that imitated cast-bronze forms.[143] Relief-carved stamps, rather like printer's type, were also used on Five Dynasties Yao-chou wares, particularly for impressing vessels with small sharp repeating designs, and this technique too can be traced to southern glazed stonewares of the -6^{th} to -5^{th} centuries.[144]

Sung Dynasty Manufacture

Excavation of a Northern Sung site at Huang-pao in +1984 revealed the lay-out of workshops then.[145] Workshop organisation was on a smaller scale than that at the Southern Sung Lung-chhüan celadon workshops in Chekiang province (see below). The site had two rectangular working areas with sunken and compacted floor surfaces. Workshops were semi-subterranean, dug some three metres into the earth, with stone foundations and upper walls composed of broken tiles and bricks. In one working area was a water jar situated near a source of fresh water, a mortar for grinding glaze materials some 60 centimetres in diameter, and two shallow clay processing ponds. At the rear was a stone platform where wheel-throwing and other modelling processes were carried out. In the other working area was a heated platform for drying unglazed wares and glaze vats.

As to raw materials used in such workshops, the local gazetteer indicated that their sources were local, lime coming from the surrounding valley of Thung-kuan 銅官 and fine white clay from the nearby mountainous area of Chhen-lu-tshun 陳爐村.[146]

Some examples of Five Dynasties Yao-chou celadon wares, especially ewers, bear elaborate carved ornament, often combining deep carving with fine detail. In the early Northern Sung dynasty a similar carved style became the mainstay of

[141] Williams (1997), p. 91 (see also fig. 6 on this page).
[142] See Roberts (1997), pp. 189–93, for a good account of the development and later history of this material.
[143] See Krahl (2000), object 60, p. 122 (a shallow tripod basin) for an example.
[144] *Ibid.*, p. 122.
[145] Hsüeh Tung-Hsing (1992), pp. 37–42.
[146] *Shensi Thung Chih*, ch. 35:3 ('*Wu chhang*'), p. 12.

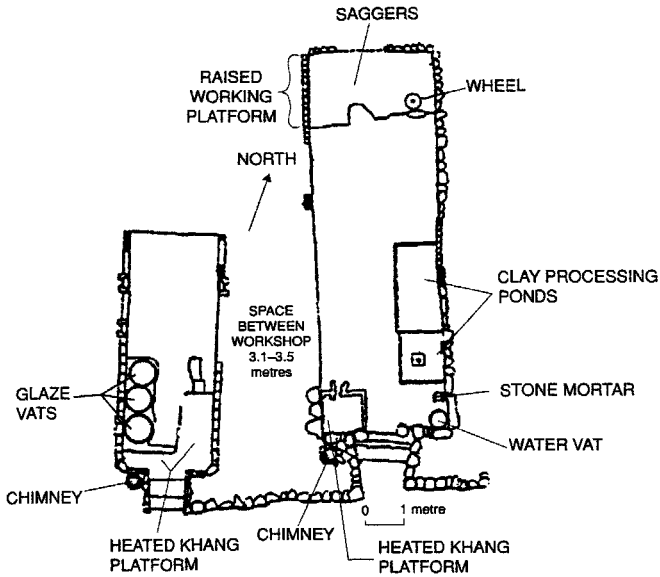


Fig. 126 Sung dynasty Yao-chou workshops at Huang-pao

Yao-chou celadon-ware ornament, particularly in the freehand engraving, carving and combing of leatherhard bowls and plates. The Yao-chou decorators used sharp-pointed and angled tools that left carved lines that were vertical on one side and sloping on the other. As Yao-chou celadon glazes appear light where thin, and dark where thick, the glazes heightened the carved designs to fine effect. Many Yao-chou celadon wares appear to have been given low biscuit-firings before glazing and this use of double-firing probably came from Huang-pao *san-tshai* practice.[147]

Freehand carving on fine Yao-chou wares gradually became more elaborate, with dense and detailed patterns sometimes covering the entire insides of bowls. However, such overall carving was time-consuming, and the labour and skill used in carving each piece separately substantial, with the designs easily marred by a slip of hand. This may have prompted Huang-pao potters to devise an ingenious technique for mass-producing 'carved' patterns through the use of moulds. That technique proved so effective that it gave results that were practically indistinguishable from the carved originals.

[147] Numerous Thang *san-tshai* and +10th- to +12th-century celadon-ware biscuit-fired sherds were seen by the authors at the Archaeological Bureau and the Yao-chou Museum's study collection at Huang-pao in +1995.

MOULDING OF YAO-CHOU 'CARVED' PATTERNS

To create such good copies of engraved patterns the Yao-chou potters carved their usual ornament into thick bowls the correct way around, but slightly deeper than usual, and with any combed details added at this stage. These unglazed 'masters' were then fired to low-stoneware temperatures. Convex working moulds were then pressed from these hollow master-moulds, and fired to between 1,100° and 1,200°C, showing water-absorption figures of between 10 and 15%.[148] The convex moulds were then set on potters' wheels and plain leatherhard bowls beaten or pressed firmly on to these decorated 'hump-moulds', before their backs were turned down to their finished thickness.[149] Once released, the designs appeared as they were carved, i.e. the correct way round, and in intaglio rather than slight relief. The process also allowed the bowls' feet to be turned at the same time as the inside shapes were being decorated by pressing.

This pressing technique made great demands on the skills of the throwers, as clay cannot be stretched except by pressure and plastic deformation, the initial fit of each bowl to the convex working mould had to be perfect. Also its soft-leatherhard state had to be exactly right and consistent overall; too dry and it would crack, too damp and it would stick. Plain and undecorated 'dressing' moulds are mentioned among the Huang-pao finds, and these may well have been used for an intermediary stage in the process, i.e. to true the bowls' inside forms prior to the pressing proper. A further aid to accuracy may have come from the use of shaped profiles on the insides of the bowls during the latter stages of throwing.[150]

The use of these plain thrown bowls would have been a more useful approach than simply placing a pancake of plastic clay over a convex mould, spinning it, and forcing the clay by pressure to take the mould's form, a technique common in modern Western ceramic production, where it is known as *jiggering*.[151] The processes of centring and throwing used for making plain bowls for later pressing, encouraged concentric alignment of the clay's minerals and this orderly arrangement helped to keep the vessels true in both drying and firing. A further advantage to the pressing of stiff-plastic thrown bowls (rather than the spreading of plastic clay over the moulds) lay in the way that the thrown leatherhard bowls could be released as soon

[148] Wang Fen & Wang Lanfeng (1995), p. 314. See also Anon. (1985), p. 54.

[149] Medley (1979), p. 5, notes that faint signs of beating appear on the backs of number of Yao-chou and Lin-ju ware celadon bowls, particularly near their rims, and that these traces of beating are rarer on Ting wares. This may be because the ornament was so much deeper on the Yao-chou than the Ting ware moulds. In the case of Ting moulds adequate 'printing' of the mould's design might be effected simply by applying pressure to the back of the bowl or plate while it was turning on the potter's wheel.

[150] 'Dressing mould: the function is to correct the shape of the damp body or to make [the] base of the wares smooth in order to eliminate the wet body's deformation.' Wang Fen & Wang Lanfang (1995), p. 313. A preliminary 'straightening' on a plain mould, before pressing on a patterned mould, was certainly the approach used at Ching-te-chen in the Chhing dynasty (see d'Entrecolles letter of +1712, translated in Tichane (1983), p. 72) and is still used today for the small amount of Ching-te-chen blue-and-white made by throwing. Shaped profiles are also used on bowls' interiors at Ching-te-chen (authors' observations in +1982 and +1995).

[151] Rosenthal (1949), p. 208.

as their feet were turned, thus allowing rapid reuse of the working moulds.[152] In the Northern Sung dynasty moulds of this style were tough and not particularly porous. Relatively high-firing temperatures preserved their sharply moulded details, and also limited their liability to damage.

The discovery of so many moulds at Huang-pao for producing 'carved' designs has shown that many Northern Sung dynasty Yao-chou celadon wares, once thought to have been decorated by carving, were probably moulded. This makes it harder to assess the proportion of carved to moulded objects made at the site during this period. Where carving is on the outside of a vessel (for instance, jars, vases and ewers) it must have been carved. Bowls or dishes that turn inwards at their rims must also have been carved, as these shapes would have made removal from the pressing-moulds impossible. For the rest moulding must be suspected before carving, as its convenience, speed and reliability would have made it the method of choice.

Parallels with Yao-chou moulding methods occur at kilns making both later versions of Hsing ware and the emerging productions of the Ting wares. The importance of silver vessels as models for northern whitewares seems to have encouraged some important differences in detail.

Influences from Silver on Chinese Ceramics

As Jessica Rawson notes:[153]

> Early whitewares were relatively thick, many of them copying not silverware but jade and bronze. Only from the Tang (Thang) period were silver shapes fairly consistently followed, presumably because only from the Tang was silver widely available. From the late Tang systematic attempts were made to reduce the thickness of porcelain vessels bringing them closer to the even thin vessel sides known in silver.

Before true moulds were used to copy silver shapes in ceramics in the +10th century, the sides of Chinese whiteware and celadon bowls were often given slight vertical indents while still soft after throwing. This allowed potters to hint at lobed silver forms, without copying them exactly. Alternatively (or additionally) the bowls' rims might be cut when leatherhard to give lobed perimeters, typical of silver designs. Both treatments are typical of whitewares and celadon wares made in the late Thang and early Five Dynasties period. Sometime in the +10th century, however, accurate reproductions of silver forms began to be made at some northern whiteware sites through the complete re-pressing and edge-cutting of thrown bowls on fully modelled moulds. Such bowls could combine lobed forms with radiating moulded

[152] Softer clay, for example from a pressed slab, would have needed to have dried *in situ* for some time before it could have been released from the mould.

[153] Rawson (1989), pp. 287–8.

ridges on their inside surfaces, and reproduced contemporary silver forms exactly.[154] Early examples were plain or sparsely decorated with light free-hand engraving. The next logical step was to exploit the potential of moulding in the production of complex surface decoration.

By the +12th century elaborate moulded surface designs were in common use at the Hsing and Ting ware kilns. These were produced by engraving leatherhard convex ceramic press-moulds before they were fired, giving rich and detailed surface ornament, similar to *repoussé* work on silver, or to brocaded patterns on silk. *Ko Ku Yao Lun* (+1388) describes how different qualities of Ting ware were regarded: 'The best have incised designs, the second best are plain, while those with brocade patterns are of third quality.'[155] This was an effective method for producing rich crowded ornament in slight relief, although the technique did have some drawbacks. To begin with, the mould-makers had to think in reverse, so that designs carved into the moulds' surfaces appeared mirrored and in relief on the surfaces of the finished bowls, dishes or plates. Also each mould was unique, and represented a substantial investment in time and skill. In this respect the Ting techniques for press moulding differed from those developed at Yao-chou. There is no evidence at the Ting kilns of the ingenious 'master-mould to working mould' sequence used to mass-produce Yao-chou hump-moulds, a process which was exploited very effectively in later Yao-chou celadon production. Moulding at the Ting ware kilns was also designed partly to provide accurate shapes for rim-down (*fu-shao* 覆燒) firing, a technique that appeared at the Ting kilns in the middle Northern Sung period,[156] but one that does not seem to have been utilised at Huang-pao. The Ting method of engraving leatherhard moulds to give raised rather than sunken ornament on the decorated vessels, appears also on much Liao whiteware, though which kiln area first exploited the method is still unclear.

AFTER YAO-CHOU

The Yao-chou kilns were influential makers of ceramics, particularly in north China, where celadon-making centres such as those in Lin-ju 臨汝 and Pao-feng 寶豐 counties in Honan province adopted the Yao-chou style, complete with its sophisticated two-stage moulding methods. Yao-chou's influence also reached to the far south of

[154] Rawson (1989), p. 286, fig. 11, cites a whiteware bowl in the Percival David Foundation of Chinese Art collection in London (PDF 173) as being an early example of this technique. Scott (1989), p. 24, dates this bowl to the +10th century, by comparison with similar items excavated from datable tombs. Plainer bowls with four simple radial ridges inside, and derived from the pressing of the thrown bowls on to simple moulds, occur at some northern whiteware kilns in China in the +9th century. Wares of this type were often exported, and the style was borrowed by Iraqi potters making tin-glazed wares at sites such as Basra and Baghdad, also in the +9th century.

[155] *Kō Ku Yao Lun*, p. 39a. David (1971), pp. 141, 306. Quoted in Medley (1979), p. 7.

[156] Cao Jianwen & Zhu Changhe (1995), p. 279. Cao and Zhu note that, strictly, upside-down firing can be traced to the Southern Dynasties and the Hung-chou kilns 洪州窯 in Feng-chheng county 豐城縣 in Chiangsi province. However, the technique used here was to fire some bowls rim to rim, rather than on the stepped setters developed at the Ting kilns.

China, where it appears at sites such as Jung-hsien 容縣 in Kuangsi province, and Hsi-tshun 西村 and Hui-chou 惠州 in Kuangtung province, and as early as the Northern Sung dynasty.[157] At both southern sites Yao-chou celadons were imitated with local materials, which were largely low-grade porcelains. Jung-hsien was particularly interesting for the way in which its potters copied the iron-green Yao-chou glazes with oxidised lime glazes, coloured with dissolved copper (II) oxide.[158]

Moulds Used at Jung-hsien in Kuangsi Province

Despite these stylistic connections, working moulds at Jung-hsien differed from the Yao-chou originals in two respects: they were mushroom-shaped rather than simply domed, and they were more usually carved direct rather than pressed from master moulds. The reason for their tall solid stems is unknown, though they may have helped to raise the mould-surfaces to comfortable working heights when attached to the potter's wheels, and/or to assist attachment to the wheelhead. In a similar manner, 'throwing from the hump' brings the clay closer to the thrower on the traditional style of Chinese stick-wheel.

The direct carving used for the Jung-hsien moulds suggests influence from imported examples of Yao-chou ware, rather than from precise understandings of how the Yao-chou potters operated. Sherds of Yao-chou celadon have been found at Jung-hsien kiln sites, together with local copies using the same patterns, but using copper-green porcelain glazes. Direct carving of the Jung-hsien moulds meant that although the Jung-hsien patterns appear very similar to those used on the Yao-chou originals, they appear more in relief (like Ting ware ornament) than the 'carved' intaglio style of the Yao-chou originals. However, later moulds from Kuangsi province (+13th century), particularly those from the Theng-hsien kilns 藤縣窯, do seem to have been re-pressed in the Yao-chou manner, as it seems unlikely that the complex raised ornament evident on the moulds' surfaces could have been managed simply by direct carving.[159]

At another southern outpost of the Yao-chou style, at the Hsi-tshun and Hui-chou kilns in Kuangtung province, directly carved moulds again seem to have been the commonest type. Here, too, local moulded copies of Yao-chou patterns are abundant on some of the finer wares, but most patterns appear in slight relief. Where freehand carving was used to decorate vessels at Hsi-tshun it was sometimes supplemented with small stamped circles and arcs. These can be cleverly integrated into the carved and combed designs and easily missed in cursory inspection.[160]

[157] For the Jung-hsien kilns, see Scott & Kerr (1993), Scott (1995). For a full discussion of the products of the Kuangtung kilns in the Sung dynasties, see Peter Y. K. Lam (1985), pp. 1–29.

[158] Zhang Fukang *et al.* (1992), p. 374.

[159] Feng Shaozhu *et al.* (1995), pp. 327–8.

[160] Peter Y. K. Lam (1985), p. 4, discusses these connections and mentions a theory that moulds for making Hsi-tshun and Hui-chou 'Yao-chou-type' celadons were initially imported from Yao-chou, then made locally when worn out. However, the Hsi-tshun and Hui-chou moulds illustrated in Lam (1983), p. 117, seem all of the 'carved in the mould' type.



Fig. 127 Mushroom-shaped mould with tall stem from Jung-hsien, dated to +1092

Spouts and Handles

The influence of silver bowls and dishes upon ceramics led to some profound changes to making methods in China, most notably in the +10th century, and at the northern whiteware kilns. Silver vessels too had their own impact on ceramic construction, particularly in the handles and spouts of wine- and water-ewers, made from the late Thang dynasty onwards. Spouts for ceramic copies of metal ewers seem to have been made from thin slabs of clay that were folded, joined and smoothed around a tapering core, which was removed before the spouts were bent slightly to imitate the metal originals. In the case of ewers' handles, these tended to be made from cut strips of clay that had been smoothed to section, and then bent to shape. These replaced earlier thicker and rounder handles that were apparently made from rolled ropes of clay.[161]

Both procedures are closer to metal working than to typical pottery-based techniques, which would normally have used throwing for spouts and 'pulling' for handles. In the +10th century these fine, tapering 'wrap-around' spouts replaced the thrown versions previously used for pouring vessels. Short cylindrical spouts had

[161] Such cut and smoothed handles are not always completely successful in translation from metal to clay as they are often too thick, too thin, or somewhat shaky in profile.

been typical of Thang dynasty stonewares, such as Huang-pao blackwares, and Chhang-sha 長沙 and Chhiung-lai 邛崍 ewers, as well as some early northern whitewares. At a few southern kiln sites, such as Chhang-sha and some Yüeh kilns 越窯, these stumpy spouts were occasionally improved by faceting.

Attempts to make more elegant spouts by throwing can be seen in Huang-pao celadon wares of the Five Dynasties period, but the approach is only partially successful, and the superior 'wrapped' spouts were adopted for Yao-chou celadons later in +10th century.[162] A subtle technical advantage to slab-made spouts of this latter kind is that they have no tendencies to twist in firing due to tensions set up in throwing, an effect that can make the final angles of thrown spouts unpredictable.[163] A similar constructional method (i.e. forming thin slabs around tapering cores) was sometimes used to make the multiple spouts applied to the funerary jars which were typical productions of southern greenware kilns in the +10th to +11th centuries.

FACETING

The influence of metal form on ceramics may also have led to the adoption of faceting on Chinese high-fired ceramics. In this process the thick outer walls of vessels or bowls are planed or scraped into vertical flats when the clay is nearly dry. Carved arcs are then often added to these facets, to give the illusion of overlapping petals. Patterns of overlapping lotus petals were a popular way for decorating the outsides of beaten silver and gold bowls in the Thang dynasty, and the style may well have encouraged this versatile ceramic technique. An early northern example of faceting (a whiteware bowl in the Ting-hsien 定縣 Museum, Hopei province) came from the foundations of a pagoda in Ting-hsien, and dated to +977. The faceting on this piece seems clumsy, but a very skilfully decorated facetted *kundika* whiteware bottle, with four tiers of lotus petals, has been excavated from the foundations of another Thing-hsien pagoda, dated to +995.[164] Some early examples of faceting from south China are seen on Yüeh ware bowls from Chekiang province dating to the Five Dynasties period, such as those from Ning-po 寧波. These have exterior lotus-petal ornament developed from facets, and suggest that the south may have been slightly in advance of the north in its use of this technique.[165] From the +10th to +14th centuries the method was used extensively at the Yao-chou and Lung-chhüan celadon kilns, for enhancing the exteriors of both bowls and covered jars. Chinese

[162] This transition can be traced in *The Ingenious and Elegant Celadon of the Five Dynasties*, and *The Pure, Fresh and Refined Pottery and Porcelain of the Sung Dynasty* sections of Anon. (1992c) (no pages numbers used).

[163] Cardew (1969), pp. 122–3, discusses this phenomenon in detail.

[164] See Satō (1981), pp. 92–4, for a discussion of these important whitewares.

[165] Hughes-Stanton & Kerr (1980), pp. 121 and 123. Attempts to give lotus-petal designs to high-fired ceramics occurred in the south earlier than this, but the technique seems rather different from straightforward faceting. See, for example, the late +5th- to early +6th-century cup and saucer in Mino & Tsiang (1986), pp. 94–5, exhibit 32. The main treatment in this case seems to be a vertical stroke with a nicked blade to give a narrow facet with a central rib, which is then enhanced by carved arcs to represent overlapping petals. Mino and Tsiang mention the Southern Dynasties Hung-chou ware sites in Feng-chheng county, Chiangsi province, as kilns that made wares similar to the piece illustrated.



Fig. 128 Water-wheel in action at Te-hua, +1995

celadon bowls decorated in this way were later imitated at kilns in Korea, Vietnam, Thailand and Egypt.

MANUFACTURE AT LUNG-CHHÜAN 龍泉

In south China, both kilns and workshops at major centres of production tended to be large in scale. Deposits at Lung-chhüan archaeological sites in southern Chekiang province revealed sherds, wasters, semi-finished products, kiln structures and kiln furniture. Heaps of raw and prepared clay included those of the most precious, iron-rich, *tzu-chin* (紫金 'purple gold') variety. There were water wheels for breaking down porcelain stone, stone stamping poles, stone mortars and different ponds for washing, draining, levigating, kneading, drying and storing clay. Whether water wheels were used in the Northern Sung dynasty is unclear, but by the Southern Sung period they were widespread. The practice of using water power to turn a wheel, which in turn activated trip hammers that pounded hard rock down to pulverised powder, was shared by several southern kiln centres, including Lung-chhüan, Ching-te-chen and Te-hua 德化. This low-technology, effective method was still in use at country kilns in China in the +1990s.

At Lung-chhüan in the Sung period, clay washing ponds were rectangular, with stone-lined sides and natural rock at the base. Washed and stirred clay-rich water was let out from the washing pool to the levigating pond through an opening. The washing pool was smaller and shallower than the levigating pond, which was large

and deep, its sides and bottom built employing used saggers. Remains of additional ponds indicated that clay could be levigated twice. By the Yuan dynasty washing and levigating ponds had become small and rectangular, usually only a single one of each, indicating that clay preparation had simplified and mass-production was underway. There were further ponds for dehydrating, kneading and storing clay, which were mostly circular and lined with either stone slabs or used saggers. A new feature from the Southern Sung dynasty onwards was an additional use of clay-storage tanks in the form of large jars, to allow clay to mature or rot. This ensured even distribution of water content and the deterioration and oxidation of any organic material in the clay, thus eliminating impurities, improving plasticity and producing higher-quality clay.[166]

The potting area included remains of a drainage system, foundations of buildings, separate areas for potting, drying of vessels and preliminary firing. There were also foundations of throwing wheels, tools for shaping, kilns for biscuit-firing, pits for holding glaze basins, mortars and grinders for mixing glaze and moulds for decoration. Some knife-like tools were made from sherds. The turn-tables of wheels were made from wood, the pits accommodating them being circular with a diameter of 50 to 60 centimetres. Rims of such pits were lined with stones, saggers or burnt clay for steadying the turn-table axle which was about ten centimetres in diameter. As time went on from Northern Sung to late Southern Sung dynasty, there was a big increase in numbers of turn-table pits, indicating an increase in production volume. The pits became more neatly constructed, and the preliminary potting and final finishing were probably carried out on separate turn-tables, indicating specialisation of labour.[167]

During the Northern Sung to mid Southern Sung period, workshop architecture was rudimentary, walls and foundations using old saggers and irregular stones. No roof tiles were recovered, so the superstructure was probably wooden and thatched. Some buildings, probably workshops, did not have paving or any other form of floor surface, whereas potters' dwellings had beaten or lined floors. In the late Southern Sung to early Yuan dynasty, foundations of workshops were found that were stone or brick, their floors being hardened with burnt clay. There were brick-paved paths outside doors, and some buildings were tiled. All this excavated evidence suggests a transition from small-scale cottage industry to commercialised production.[168]

DOUBLE MOULDING

Early moulded ceramics made in China constitute covered wine vessels that copy bronze forms.[169] Very different in style, but also apparently moulded, are the

[166] Li Dejin (1994), pp. 86–8.
[167] *Ibid.*
[168] *Ibid.*
[169] One example of a very large vessel is illustrated in Anon. (1988a), National Museum of Chinese History, p. 61, fig. 4-1-4.

unusual carbonised and burnished Warring States or Chhin dynasty 'amphora' of squarish section, with large round bosses on their sides, and sporting two large handles. These derive from Szechuan province and are believed to be Chinese copies of a 'vessel type of non-Chinese peoples to the south west.'[170] They appear to have been press-moulded in two halves into hollow moulds that divided the form diagonally across its square section. The halves were then joined. The dating of these wares has always presented a puzzle, with 'Late Neolithic' to 'Chhin dynasty' being variously proposed.

Double-moulding, where clay slabs are squeezed between inner and outer moulds, seems to have been first used for the mass-production of moulded Chün ware flowerpots. These robust but finely made vessels bear thick bluish glazes on their exteriors that have been covered with thin washes of copper-rich pigments. During firing this combination reacted to give complex red, fuchsia and purple tones on bluish and opalescent Chün-glaze backgrounds.

There is a debate about the dating of this category of Chün ware 鈞窯. Many scholars in the West and in Taiwan date both the thrown version (which are often enhanced with applied 'nail-head' studs and moulded 'cloud-shaped' feet), and the moulded square, rectangular and hexagonal versions, to the Chin, Yuan or even Ming dynasties. In China, however, these moulded Chün ware flowerpots (which often have size-numbers impressed in their bases) tend to be considered 'official Chün wares' and given Northern Sung dynasty datings.[171]

In terms of practical construction 'numbered Chün ware' flowerpots present some problems in interpretation as some have inward-curving walls that would have made it impossible to release complete inner-mould forms, once the shapes were finished. It may be that conventional hollow press moulds were used to make the main outer forms, but then the inner forms were refined one section at time, by pressing firmly with just one section of the inner-mould shape while the vessel was still in its main mould. Squeezing between double moulds has also been suspected for some unusually elaborate Yuan dynasty Ching-te-chen dishes with deeply moulded bodies and bracketed rims. Although these are sharply moulded on their insides, however, corresponding definition on their backs seems less clear, which

[170] A good example, 33.5 centimetres high, is illustrated in Krahl (2000), p. 101. The style is discussed on the facing page, p. 100. A bronze vessel in this style is in the Cernuschi Museum in Paris, although it has been suggested that this may be a Sung dynasty piece. See Beurdeley & Beurdeley (1974), p. 45, fig. 26.

[171] Li Huibing [Li Hui-Ping], for example, believes that: 'Excavations have proved that the Juntai [Chün-thai] 鈞台 kiln at Yuxian [Yü-hsien] 禹縣, Henan [Honan], was the second official kiln and followed not long after the Ru [Ju] kiln 汝窯 . . . The Jun [Chün] kiln probably started after 1118 and was abandoned at the time of the destruction of the Northern Song [Sung] imperial court. Examples of Jun wares found at the site are identical to Jun official wares in the Palace collections.' Li Huibing (1994), pp. 30–2. The Yü-hsien finds, illustrated by Li Huibing (*ibid.*, p. 29, fig. 6), include both thrown and moulded examples. However Kerr (1993), p. 151, writes that: 'Many western writers consider the archaeological record to be circumstantial and believe that form, style and mould manufacturing techniques dictate datings in the Jin [Chin], Yuan and Ming dynasties.' Kerr notes that Medley (1974), pp. 90–6, Ayers (1980), nos. 102 and 103, and Morgan (1982) take this later manufacture view, which is echoed in the meticulous study by Taiwan scholar Lo Hui-Chhi (1997). One possible cause for dating confusion at the Chün-thai site may be that the waster-heaps were inverted in the search for saleable wasters, still stuck in saggers, in the early +20th century, to meet the demands of foreign collectors. Pamela Vandiver, pers. com. +2002.

suggests careful 'repair' after pressing, rather than direct application of outer mould or moulds to the dishes' backs.

MANUFACTURE AT CHING-TE-CHEN FROM THE FIVE DYNASTIES TO THE YUAN DYNASTY

Firing arrangements at Ching-te-chen have already been discussed at some length (pp. 365–78) and this section will concentrate on further information about ceramic forming processes derived from archaeology and from texts. As indicated in Part 1, information concerning Ching-te-chen is more copious than that for any other production area. Another special feature about the kilns at Ching-te-chen was that they exploited to a marked degree the principles of division of labour and mass-production. In addition, because raw-glazing was used so widely at Ching-te-chen, its production methods cleverly integrate glazing with such finishing stages as turning and decorating. But as Robert Tichane notes, very little was actually invented at Ching-te-chen. Instead, the workshops were exceptionally skilled at adapting ceramic techniques developed elsewhere in China.[172]

Thao Chi described demarcation of working areas depending on skill specialisation: potting, sagger-making and clay preparation. Different training was required for throwing, turning, glazing, impressing, carving and incising, in other words clear division of labour was vital for successful manufacture. A special 'warm room' was built for winter potting and drying when the clay was prone to freezing.[173] The earliest products from the Ching-te-chen area are Five Dynasties greenwares with grey stoneware bodies. These have been found in the lower strata of kiln debris on the east slope of Liu-chia-wu 劉家塢 and south-east from Lung-thou-shan 龍頭山.[174] Both sites are within the 100-acre kiln-complex surrounding the old village of Hu-thien 湖田. The upper levels of these Five Dynasties sites have yielded both white porcelains and green-glazed stonewares, and these show strong similarities in their forms and general manufacturing technology. Hughes-Stanton and Kerr note that:[175]

> From the Five Dynasties period, green and white wares were made at such kilns local to Jingdezhen (Ching-te-chen) as Shihuwan (Shih-hu-wan 石虎灣), Shengmeiting (Sheng-mei-thing 勝梅亭) and Huangnitou (Huang-ni-thou 黃泥頭).

At similar sites near to Ching-te-chen (particularly Yang-mei-thing 楊梅亭 and Hu-thien itself), visited by the authors in +1982, it was possible to see Five Dynasties greenwares and whitewares mixed in the same spoil-heaps (see Figs. 144 and 145). Stonewares and porcelains both showed typical early +10th century Yüeh-ware type forms and manufacturing methods. They included both plain and lightly engraved ewers, together with bowls having Thang dynasty-style thickened rims.

[172] Tichane (1983), p. 421.
[173] *Thao Chi*, reproduced in Pai Khun (1981), pp. 40–1.
[174] Liu Hsin-Yüan & Pai Khun, quoted in Tichane (1983), p. 395. See also Pai Khun (1981), p. 39.
[175] Hughes-Stanton & Kerr (1980), p. 46.

Ching-te-chen white porcelains became slightly thinner in the early Northern Sung period and their glazes more transparent. This resulted in the celebrated *chhing-pai* 青白 material that not only dominated Ching-te-chen production until the early +14th century, but was also imitated at porcelain sites across southern China. The Ching-te-chen *chhing-pai* wares made during this period were 'fairly plain' and the forms 'simple and strong' and the bowls were fired the right-way up.[176] In the mid Northern Sung period, engraved decoration became more widespread, using angled tools similar to those developed at Yao-chou. The use of rather coarser materials and thinner glazes at Ching-te-chen resulted in lower-quality products than the Yao-chou kilns, albeit lively ones. One Ching-te-chen decorative feature of the Northern Sung period is held to be the 'dotted comb' method, where the comb is sometimes repeatedly pressed, and sometimes 'walked', on the clay surface. This treatment supplies an effective counterpoint to carving.[177]

Moulds were introduced to Ching-te-chen later than in the north, and used the Ting rather than Yao-chou approach, i.e. the moulds were carved direct and the designs appear on the vessels in light relief. The appearance of moulded bowls at Ching-te-chen coincides with the adoption there of the *fu-shao* (upside-down) method of firing, for moulding is an ideal way to achieve the dimensional accuracy needed for the process.[178] Techniques for press-moulding a wide variety of covered boxes were also adopted at Ching-te-chen, from the late Northern Sung dynasty onwards.[179]

Moulding in light relief is characteristic also of *shu-fu* 樞府 wares, which first appeared at Ching-te-chen early in the Yuan dynasty. These often bear moulded designs on the inner walls of bowls and dishes, while the flatter centres of the forms are enhanced by light carving. That approach was also used on the earliest styles of Ching-te-chen copper-red monochrome wares. Throwing into moulds (again often to produce designs in light relief) occurs throughout this period, thereby continuing a method already used successfully for Yao-chou wares in the Five Dynasties period.

MANUFACTURE AT CHING-TE-CHEN IN THE MING AND CHHING DYNASTIES

Forming techniques multiply with the appearance of underglaze-blue and underglaze-red painting at Ching-te-chen in the +1330s. Huge dishes, jars and vases were first produced at that time, mostly at Hu-thien, and particularly for export to West Asia. The manufacturing techniques adopted were largely those used already by Lung-chhüan potters, i.e. either direct throwing, or the pressing of thick thrown dishes on to giant convex moulds. *Thao Shuo* (Description of Ceramics, +1774)

[176] Chen Baiquan (1993), p. 20.

[177] Medley (1979), p. 8, notes that the technique also appears on contemporary celadons from Chekiang province, and seems to be 'a distinctively south-eastern and southern treatment'. Hsi-tshun wares from Kuangtung province can also show 'dotted combing' decoration.

[178] Chen Baiquan (1993), p. 21, puts the introduction of *fu-shao* firing at Ching-te-chen at the mid Northern Sung dynasty, very close to that suggested for the Ting ware kilns.

[179] *Ibid.*, p. 24.

described how after the clay had been shaped on the wheel and dried out, it was put into a finishing mould and pressed down gently by hand until the shape was regular and the thickness uniform. It was then taken out to be dried in the shade ready for final trimming down with a blade.[180] Large jars, vases and bottles were made by the stacking and sticking together of thrown and turned sections. A more difficult, and probably more expensive technique, involved the press moulding of large square, hexagonal and octagonal flat-sided vessels. As mentioned on pp. 440–2, pressing between double moulds has been suspected for some of the more complex and sharply defined of large +14th-century porcelain dishes, but it is hard to be certain that the method was actually used. By the +17th century, *Thien Kung Khai Wu* (+1637) makes it plain that yellow-clay moulds were employed, either in one piece or in sections; the clay paste was pressed into the mould, the seams painted over with liquid glaze and after firing a whole, unjointed piece resulted.[181] Moulds shrank in manufacture as they dried. In order to make moulds in which this shrinkage was accurately predicted, a special group of experienced artisans was employed.[182] Traditionally either unfired clay moulds were used, or fired biscuit porcelain for the very finest pieces. It was not until the very end of the Chhing dynasty that experimental use of the now ubiquitous plaster of Paris moulds started.[183] After all the forming processes had been completed, items were painted and inscribed, sprayed with a little water, and were then ready to be glazed.[184]

Very large wide-mouthed water jars were made in two horizontal sections, the sections being luted and the joint temporarily braced by exterior wooden pegs. Small-mouthed jars were also made in sections, but could not employ wooden pegs inside. Instead, a circular ring of porcelain that had already been fired was put inside to reinforce the joint, which was held outside by wooden pegs. Multifaceted, square, ribbed and angled items were slab-built, the pre-prepared paste shaped by boards into slabs using cotton cloth as a separator. The artefacts were cut into shape by knife and the sections luted together with slip. As the *Shih Wu Kan Chu* (+1591) acknowledged, slab-built pieces were much more difficult to make than thrown ones, both in terms of time and potters' skills.[185] In the +16th century square vessels such as boxes, vases and plates were fashionable but hazardous to produce, having a success rate of no more than one-fifth. One particular problem was damage caused by the differential drying rates of such thick-walled vessels.[186] These prestige, large commissions often suffered heavy losses in production, largely because of the high shrinkage that Ching-te-chen porcelain undergoes in firing, that made large porcelain objects particularly prone to distortion and to fire-cracking at maximum kiln temperatures.

[180] *Thao Shuo*, ch. 1, pp. 7a–b.
[181] *Thien Kung Khai Wu*, ch. 7, pp. 6a–b. Sun & Sun (1966), p. 147.
[182] *Ching-te-chen Thao Lu*, ch. 1, p. 3b.
[183] Anon. (1959), p. 285.
[184] *Thien Kung Khai Wu*, ch. 7, pp. 6b–7a. Sun & Sun (1966), pp. 147–8.
[185] Quoted in *Thao Shuo*, ch. 1, pp. 5b–6a.
[186] *Khuei Thien Wai Chheng*, p. 22. *Chiangsi Sheng Ta Chih* (1597 edn), ch. 7, p. 19a.

Such were the prime forming-methods used at Ching-te-chen but, as with most kiln sites in China, Ching-te-chen's main production throughout its history has been the bowl shape that is thrown on the potter's wheel, and particularly the smaller sizes used for drinking tea, serving rice and individual consumption of food. In the Ming and Chhing dynasties, texts noted that nine-tenths of all wares made were what was termed 'round wares', i.e. open forms like bowls and dishes that were shaped on the potter's wheel.

Li Chien-Sheng's film (+1996, see p. 68) shows how the potter starts his production by kneading about 25 kilograms of porcelain clay on a small, low, sloping bench in a corner of the workshop. 'Bull's nose' kneading is used here, where the potter compresses the clay with the base of his palms, producing the characteristic 'bull's nose' in the centre of the clay. Kneading proceeds with lighter and lighter pressure until the clay is coaxed into a truncated cone, at which point its wider end is rocked lightly on the bench to make a domed surface. The clay is then dropped on to the wheel's centre and a series of 'round wares' are thrown 'off the hump'. The thrower sets the wheel spinning anti-clockwise with a stick that engages with shallow holes near the wheel's perimeter, building momentum until the wheel is running steadily at about 100 rpm. Laying the stick aside the potter then splashes water on the cone's top, and opens the clay to form the bowl, mainly through pressure between the thumb and fingers of the right hand. The inside shape is then refined by using a curved unglazed porcelain tool, working against the run of the clay on the *left*-hand side of the bowl's interior, while supporting the clay outside. Making is unhurried but rapid, and it takes about 30 seconds to complete a bowl. To remove the bowl a deep cut is made on the turning clay with a split bamboo stick, well below the bowl's form, leaving a tall 'stem' of clay, which can be nipped off by closing the fingers on the spinning clay.

The new bowl is set at an angle of about 45° on a long narrow board, a system that maximises the number of bowls a board can take. When full, the boards are borne away and slid on to stillages above the potters' heads in the workshop.

When stiffened sufficiently by air-drying, the bowls are brought back to the wheels for truing, with the truing wheels often being lighter versions of the throwing types. In the truing process a leatherhard inverted bowl is banged over a domed mould, attached to the centre of the wheel. To the observer this seems a risky act as it appears as if the raw bowl could be easily split by the process. However, not all is as it seems. During making the inside base of the bowl is made flatter than eventually intended. It is this flat interior that the domed top of the truing mould is compressing, rather than stretching the bowl's sides.[187] The shape of the bowl is also brought back to the round on the truing mould with a skilful and rapid smacking as

[187] The reason for this detail must be that 'throwing from the hump' makes it difficult to compress the inside of the bowl sufficiently, which in turn can lead to spiral cracking in the base when drying or even in firing. By deliberately flattening the bowl's centre in making, and then compressing it on the truing mould, this cracking problem can be pre-empted. As Cardew (1969), p. 110, explains: 'S-cracks . . . often do not appear until after turning, sometimes even after biscuit-firing. The cause is that the bottom of the pot, by the nature of the technique, does not receive nearly so much consolidation and pressure as the walls.'

it rotates. This restores some mobility to the clay, and allows it to be trued without cracking. The rough 'stem' of the bowl (later to become its foot) is also improved at this stage by a rapid pinching and smearing until it is round, followed by a light beat on its top to make it level. All this takes a few seconds per bowl, after which the loaded boards are returned to the racks for further drying.

When nearly dry, the bowls are brought back to the wheels for turning, with the bowls being set on domed chucks similar to those used for truing.[188] After a light tap to make the inverted bowl spin true, the potter damps its sides with a large goat-hair brush, takes a large square-ended metal turning tool, cuts the bowl's base flat, then makes a deep vertical cut to define the outside of the foot-ring. The bowl's exterior is then shaved to meet this cut, with the near-dry porcelain clay flying from the metal blade edge in a shower of dust. The bottom of the foot is then shaved to a slightly hollowed flat, but still left solid. *Thao Shuo* mentioned that the carving-out of the foot was a specialist process.[189]

Textual sources confirm that the making of 'round wares' was divided between two groups of artisans, one taking big pieces 1–3 feet (*chhih* 尺) in diameter, the other small pieces less than a foot across. Clay was kneaded to the right consistency by another group of workmen who put it on the wheel for the potter, who set the wheel in motion using a bamboo pole. Then he rapidly threw off the hump of the clay while the wheel was still in motion. The wheel was such a vital item of equipment that carpenters were retained on site to effect repairs when necessary.[190] To achieve thinness of body the vessels were pared down while leatherhard. This was done on a wheel with a wooden stake in the middle to support the piece, padded with silk floss to prevent damage to the insides of vessels.[191]

Closed forms like vases were also made in sections on the wheel, then green-dried and pared down with a cutting tool, the surface being polished till very smooth with a large goat-hair brush moistened with water.[192] It was said that some imperial wares were left unglazed and in a rough state for over a year, so that the clay became extremely dry. It was then easier to turn them till they were paper-thin.[193] No mention is made of glue or other additives to increase the green strength.

The Ching-te-chen potters' labours were remembered in song. *Ching-te-chen Thao Ko* (Potters' Songs from Ching-te-chen, +1824) includes this ditty celebrating the absolute accuracy of skilled craftsmen's work, as no. 5 in a section on making blanks and moulding:[194]

[188] The quartz-rich porcelains of south China are best turned when nearly dry, an approach impractical with the clay-rich northern stonewares, which become hard and brittle at this stage.
[189] Thang Ying's illustration 14, included in *Thao Shuo*, ch. 1, p. 9b.
[190] Thang Ying's illustration 6, included in *Thao Shuo*, ch. 1, pp. 5a–b. See also *Ching-te-chen Thao Lu*, ch. 1, p. 4a.
[191] *Ching-te-chen Thao Lu*, ch. 1, p. 4b.
[192] Thang Ying's illustration 7, included in *Thao Shuo*, ch. 1, pp. 5b–6a.
[193] *Ti Ching Ching Wu Lüeh*, ch. 4, p. 17.
[194] Yang Ching-Jung (1994), p. 34.

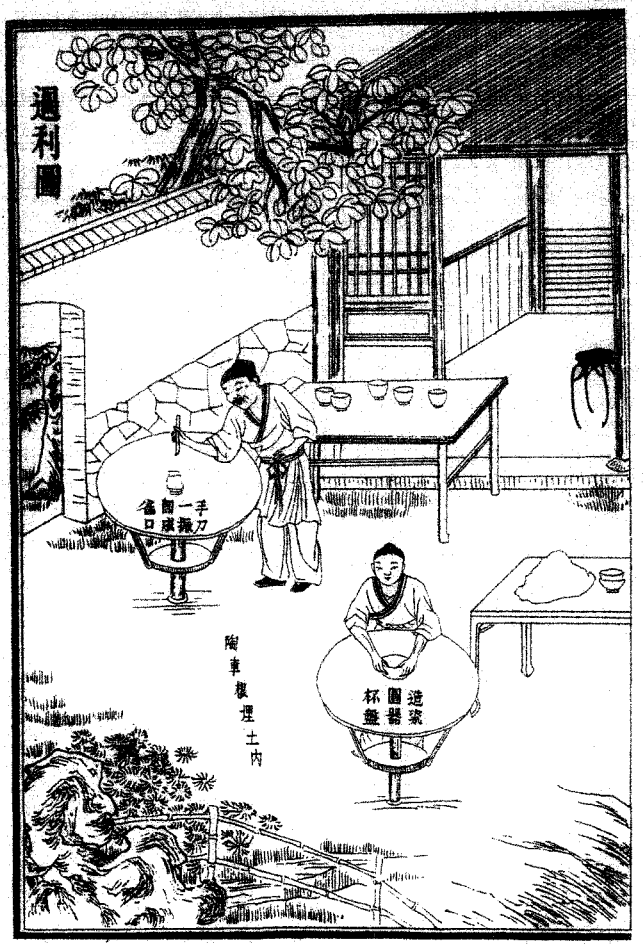


Fig. 129 Top of picture: turning, using a goat-hair brush. Lower picture: throwing on the wheel. From *Thien Kung Khai Wu* (+1637).

Several round wares are placed on the wheel
Under [the potter's] hands you can see the bodies taking shape
Cups and saucers circulate under [the pressure] of two fingers
All are measured with the stave [*ping*], no need to shave them down

幾家圓器上車磐
到手坯成宛轉看
杯碟循環隨兩指
都留長柄不雕鏝



Fig. 130 Dipping wares in glaze. From *Thien Kung Khai Wu* (+1637)

DECORATING, GLAZING AND THE COMPLETION OF TURNING

The *ping* 柄 stave was mentioned in an annotation to another song in *Ching-te-chen Thao Ko*, no. 12 in the section on carving out the foot:[195]

[195] *Ibid.*

For blanks there is the *ping*, which is three inches long to facilitate applying the colours. After glaze blowing-on has been completed the guide lines are removed. The carving out of the foot and the writing of the mark goes to another potter.

坯先有柄, 長三寸, 便于畫料. 吹釉工畢, 旋去蓋線, 挖足落款, 另歸一工.

Thang Ying 唐英, in his descriptions of illustrations depicting pottery-making, also mentioned a handle or stave called *ping*. Painting materials were ground in mortars, placed in rows on low benches and rotated in the hands of the specialist artisans who ground pigments in them. To stabilise the work, upright wooden poles were fixed to the benches that supported horizontal planks pierced with holes to hold the handles (*ping*) of the pestles.[196]

Most Ching-te-chen porcelains are glazed in the raw, unfired state, with turning, glazing and decorating all carefully integrated into the finishing processes. Underglaze-blue designs, for example, would be painted inside raw bowls that had their exteriors turned but their feet left solid. Once the painting was dry, glaze would be poured in, and then immediately poured out, while rotating the bowl to ensure that the interior was evenly covered.[197] Any slight drips on the bowl's exterior would be carefully removed. Once the glaze had been neatly finished at the rim, the outside could then be decorated with underglaze-blue pigment. The bowl was usually placed on a lightweight wheel for painting the banded lines.[198]

Outside glazing was usually managed by submerging the bowl the right-way up exactly to its rim, until outer and inner glazes met. This was helped by supporting the bowl underneath its solid foot with a light bamboo tool shaped like a back-scratcher. The logic of leaving the foot solid until this stage becomes apparent at this point, as a bowl with a finely turned foot would be far more likely to crack or collapse during these later decorating and glazing stages.

Thang Ying's illustration of 'pouring glaze' from *Thao Yeh Thu Pien Tzhu* (see pp. 25 and 27–8) was included in *Ching-te-chen Thao Lu* (+1815).[199] It confirms that in the +18th century small bowls and dishes were dipped in glaze.

The traditional method of painting glaze on with a hair brush was also used, together with the newer style of spraying glaze on through a bamboo tube with a fine gauze filter.

The bowl was now practically complete. Once dry, it was returned to the wheel and the foot's interior turned out. Reign marks, rings or commendation marks might now be painted with underglaze-blue, with these in turn covered by glaze,

[196] Description to illustration 10, included in *Thao Shuo*, ch. 1, p. 7b.

[197] Another Ching-te-chen method for interior glazing, illustrated by Tichane (1983), p. 157, is centrifugal spinning. In this technique an exact measure of glaze is poured inside a fast-spinning bowl, and the glaze distributes itself evenly on the bowl's interior.

[198] One of the surprises of the film made in +1996 by Li Chien-Sheng is the sight of young women painting accurate bands on the bowls' exteriors freehand, by simply holding the bowls upside-down with the left hand and painting with the right.

[199] *Ching-te-chen Thao Lu*, ch. 1, pp. 5a–b. Sayer (1951), p. 8. Thang Ying also mentioned spraying (a Chhing dynasty practice) and painting (the ancient method) as being used for applying outside glazes. Dipping, as described above, was also used in Thang's time for glazing smaller wares.

often applied with a soft brush. After chamfering the edges of the foot to remove any stray glaze the bowl was nearly complete, but was often returned to the wheel one further time, to rub the glaze lightly to avoid pinholes where air-bubbles were trapped in the glaze surface. After this treatment the bowls could be completely dried, ready for firing.

The numerous and discrete stages described above demanded very different levels of skill from the workers, with throwing and decorating being the most difficult, and truing, turning and glazing being fairly routine. It was one of Ching-te-chen's greatest strengths (in terms of organisation and efficiency) that the stages in making were divided amongst numerous specialised workers. That was noted by Père d'Entrecolles in his early +18th-century letters from Ching-te-chen:[200]

> It is surprising to see with what speed these vessels pass through so many hands. It is said that one piece of fired porcelain passes through the hands of seventy workers. I have no trouble in believing this after what I have seen myself, for these great laboratories have often been for me a kind of Areopagus, where I have preached of Him who made the first man out of earth, and from the hands of whom we go out to become vessels of splendour or disgrace.

PRODUCTION METHODS FOR I-HSING 宜興 STONEWARES

While Père d'Entrecolles was living and ministering in Ching-te-chen, and recording its life and manufacturing methods, huge volumes of porcelain were being made for the Western tea-trade. The wares were often shipped from China packed in chests of tea, to protect them during transport. In these same cargoes, but from an entirely different source, were sent thousands of unglazed red stoneware teapots from I-hsing in Chiangsu province. It is interesting that red I-hsing wares incorporated approaches to manufacture quite alien from those developed at Ching-te-chen, particularly in the way that the potter's wheel played little or no part in their creation.

Of all the methods used to manufacture Chinese ceramics, those applied to the production of I-hsing red stonewares are closest to the working of sheet metal. In fact, and surprisingly, this is one aspect of Chinese ceramic production in which beaten metal prototypes seem to have played little part.

The 'sheet-clay' techniques at I-hsing have been used to make a wealth of vessels that vary from convincing representations of organic forms to exercises in abstract geometry. The latter would deserve the description 'reductionist modernism', had they not been made in the +17th and +18th centuries. The most famous examples of I-hsing red stoneware, and those displaying the richest and most creative range of designs, are the teapots. Those vessels combine lively designs with the famous properties of I-hsing stoneware clays in the successful brewing of tea (see pp. 273–7). However, trays, flower vases and unglazed-red cooking pots are also made from this versatile material, although hardly ever by the technique of throwing on the wheel.

[200] Tichane (1983), p. 73, translation of Père d'Entrecolles' letter of +1712.

Innumerable manufacturing processes and sequences have been developed at the I-hsing workshops, but those applied to the traditional production of unglazed red teapots are perhaps the most representative.[201] The best I-hsing teapots are entirely hand-built from thin slabs of clay, a process that demands particularly even, well-tempered clays, with low contents of trapped air. To these ends traditional potters may spend as much as two days beating the clay with large heavy mallets until the paste develops the subtle sheen that indicates sufficient tempering, although nowadays de-airing pugmills replace this chore for all but the most expensive objects.

Once the clay is prepared for making, small blocks are beaten into thin slabs on thick hardwood benches, using small wooden mallets with slightly convex faces and rounded backs.[202] Once beaten, the thin slabs of plastic clay are cut accurately to size using simple tools like dividers, rather as a tailor would cut the cloth to make a suit. A circular and a long rectangular slab are then taken to construct a plain cylinder, with the disc forming the base and the rectangle the sides. Once the joins are lapped and smoothed, the cylinder is gently beaten inward at its top, using the fingers inside as an 'anvil' and the light wooden bat outside as the 'paddle'. This narrowed top is then closed with another clay disc, which in turn is lightly beaten into position. The fully closed form is then smoothed and trued with a thin flexible tool made from buffalo horn, which is kept in a water-pot when not in use.

The whole shape is then inverted, making the top the new base, and what was once the base-disc is removed. This allows the fingers inside, and the upper wall is again lightly beaten inwards by paddling to produce a nearly spherical form.
At this point the process becomes more involved as the maker takes two more clay discs, superimposes them on the bench, and cuts out and removes a slightly smaller disc from the topmost disc only. This smaller disc is kept, as it will eventually act as the teapot's lid. The superimposed discs are now placed over the hole in the top of the teapot body, and carefully blended with the sides of the vessel. The closed, near-spherical body is then smoothed with the buffalo-horn tool, with the air trapped inside the vessel providing resilience to the form during finishing. Once the body has stiffened sufficiently a hole is cut in the top, smaller than the lid, which leaves a ledge on which the lid will eventually sit. This hole is plugged with a temporary wooden disc to keep the body-shape true in early drying, while attention turns to making handles and spouts.

I-hsing teapot spouts are often formed first as solid clay shapes, allowed to stiffen somewhat, and then hollowed from both ends with loop-ended tools and fine knives. Solid handles are also hollowed somewhat, for insulation, for weight reduction and as an aid to successful drying. With all these elements complete, the final assembly can take place: a knob or ring may be added to the lid, and the spouts and

[201] Methods are described from the authors' observations at I-hsing in +1982 and +1985. See also DeBoos (1997), pp. 90–3, and Silverman (1997), pp. 10–12.

[202] An example bought by one the authors (NW) in I-hsing in +1985 weighed 530 grams and had a slightly convex beating-face some eight centimetres by fourteen centimetres. The mallet was carved from a single piece of wood.



Fig. 131



Figs. 131–132 Making a teapot at I-hsing, +1985

handles attached with sticky clay. Repeated smoothing with the flat buffalo-horn tool during the final finishing stage develops a subtle bloom to the clay surface, and this improves with use and handling once the objects have been fired.

Since at least the mid Ming dynasty I-hsing red teapots have been regarded in China with an affection once reserved for Chien *temmoku* 天目 tea bowls. However, production of I-hsing stoneware nearly died out in the late +1940s when, as Garnsey and Alley record:[203]

> Living conditions were so precarious that the potters had scattered to other areas for sheer survival, taking work as coal miners, carriers or indeed anything that would give them some sort of a livelihood.

This nearly extinct industry was rescued in +1950 by Government intervention. Old potters were brought back to I-hsing to train younger workers in traditional making techniques, and the industry revived. I-hsing hand-made teapots now enjoy enormous popularity, in China, in Japan, in Taiwan and also in the West.

The essential manufacturing processes and sequences, outlined above, may be supplemented today by pressing the nearly complete forms into hollow moulds, further to standardise and regularise their designs. A great deal of freehand modelling, and the application of moulded details, have also long been used with I-hsing stonewares, notably for vessels based on natural forms. However, the heart of the I-hsing process is this novel sheet-clay-working technique, supplemented with beating, which has few parallels with other ceramics-producing centres within China.[204]

SUMMARY OF PART 4: 'MANUFACTURING METHODS AND SEQUENCES'

Despite the many advances made in ceramics in China over the past two millennia, particularly in the development of high-temperature bodies and glazes, objective study suggests that most important making methods were developed by potters and mould-makers in the late Neolithic and Bronze Age. Coil-built vessels of impressive accuracy and style typify the Yang-shao culture of north China, while in the later Neolithic, particularly in Shantung and Chekiang provinces, the fast wheel was applied to the production of very complicated and original vessel-forms. These were often thrown in a number of parts and in some cases joined after, rather than before, turning. That technique was revived thousands of years later in south China for the

[203] Garnsey & Alley (1983), p. 82.

[204] A rather different type of sheet-clay technique has been practised since the Ming dynasty at the Shih-wan 石灣 and Fo-shan 佛山 kilns of southern Kuangtung province. The larger figures for which these kilns are famous are often built free-hand by taking a large sheet of clay that has been flattened by beating with the base of the hands, then rearing this up, and deftly folding, pressing and modelling the sheet into the form of a tall robed figure. In this southern tradition, the heads, hands and feet of the figure are often added separately, and sometimes made from darker clays. The technique was demonstrated in London in the +1980s by visiting Shih-wan potters. See Thao Jen (1979), pp. 289–92, for an account of Shih-wan making methods.

manufacture of porcelain.[205] Tall hollow feet were common on north-eastern Neolithic wares, and these were often finely turned and accurately perforated. Lids were made precisely to fit the vessels they covered, and Neolithic handles were refined in section and strong in form. In some cases separate spouts were applied to Neolithic pouring vessels, and many trilobate vessels were constructed from five or six separately thrown elements, to make complex and fluent vessel-shapes. In short, the foundations for China's throwing skills were established in the later Neolithic period, and few advances on its essential methods appeared over the next four millennia.

In the Shang dynasty loessic ceramic moulds were devised for casting ritual bronze vessels and weapons to levels of precision and volumetric complexity that remained unmatched and unsurpassed until the later +20th century. The construction of ceramic building materials, that had its origins in the Neolithic period, developed between the Western Chou and Han dynasties to include a range of products of surprising intricacy and diversity. And in the Chhin and Han dynasties related loessic materials were used to make hundreds of thousands of press-moulded ceramic figures for important tombs, a proportion of which were as large as life and realistically painted.

After these constructional triumphs in the late Neolithic and Bronze Age, relatively few methods for making ceramics were introduced in China. Those that were, tended to combine the processes of throwing with moulding, the most important innovations occurring at Yao-chou and Ting ware workshops of the +10th to the +12th centuries. Metal-derived methods of clay-working, such as the faceting of bowls and jars, the folding of spouts and the cutting of handles, also appear at this time.

Organisation rather than innovation characterises Ching-te-chen's contribution to ceramic production in China, while the methods of the I-hsing potters (so nearly lost in the late +1940s) survive as an interesting variation on the myriad ways that plastic clays have been manipulated in China.

[205] An extreme example of this approach is seen in Ching-te-chen in the +15th century (Ching-Thai reign period) where the stems and bowls of stemmed cups were thrown and turned separately and not united until the raw-glazing stage, when they were joined with glaze rather than with slip. See Liu Hsin-Yüan & Pai Khun, quoted in Tichane (1983), pp. 412–13.

PART 5: GLAZES

ASH-GLAZES

ORIGINS OF CHINESE GLAZES

The discussion of glass theory and the history of glazes in Part 1 established the level of technology that operated in the world when Chinese glazes first appeared in the early Shang dynasty.

The earliest deliberate Chinese glazes were at once more primitive and more advanced than the ancient glazes of West Asia. They were more primitive in that their origins were largely accidental. The Chinese glazes were also unfritted (not pre-melted) and their colours came simply from any impurities (mainly iron, titanium and manganese oxides) that their raw materials contained. But they were also significantly more advanced than Near Eastern glazes in that they were high-temperature rather than low-temperature compositions. This vital difference resulted in the intensely hard surfaces typical of high-calcia stoneware glaze compositions. Early Shang dynasty glazed stoneware also shows evidence for the deliberate manipulation of kiln atmosphere, perhaps from the prevailing Neolithic tradition of reduction-fired earthenware.

As described in Part 2, many surface clays in southern China show a natural refractoriness, which meant that Neolithic potters in the south were often rewarded with tougher ceramics when they raised the firing temperatures of their kilns. In north China, similar rises in Neolithic firing temperatures would have caused a collapse of the setting, followed by a melting of the wares into a dark greenish glass. In south China, the more refractory raw materials consolidated well in the kilns from moderate body-glass formation, and also developed good fired-strength through some growth of mullite in the clay bodies. The toughness seen in those early wares also benefited from the widespread Neolithic practice of reduction-firing as ferrous (iron II) oxide (FeO) tends to act as a body-flux at temperatures above about 900°C. The hard grey ceramics produced in south China by these processes have enjoyed a long history. The material was first seen in the late Neolithic period, and their making principles survive in southern brick- and tile-production to the present day.

Wood was used to fire these early Chinese stonewares and, as firing temperatures began to exceed about 1,150°C, a natural 'kiln gloss' tended to develop on the wares. This happened when the oxides of calcium and potassium present in the wood ashes reacted with the silica and alumina in the clay bodies to make an 'accidental' glaze, a process assisted by the highly siliceous nature of many southern ceramics. The first Chinese glazes must therefore have been natural effects, caused by incandescent wood ash, carried through the kiln by the draught of the fire, attacking the siliceous surfaces of the stoneware clays and turning them to glass.

DATING THE FIRST CHINESE GLAZES

Glazed stonewares from the early Shang dynasty have been found at sites in Hupei and Chiangsi provinces in the south and at Honan province in the north.[1] This would place the first glazing of ordinary clays in China to about the same period as the first glazing of ordinary clays in West Asia, the difference between the two traditions being that the Chinese glazes were largely accidental, while the Near Eastern glazes represented a further stage in a glaze tradition that was already some 2,500 years old.

Technical accounts of early Chinese glazes are scarce, but two early glazed stoneware sherds have been studied from the Yüan-chhü 垣曲 site in southern Shansi province, one of four important city sites of the early Shang dynasty.[2] The wares were found in an Upper Erh-li-kang 二里崗 stratum at the site that also contained ceramics from late Yang-shao 仰韶 and Erh-li-thou 二里頭 culture levels. The earlier levels contained no glazed stonewares, but instead were rich in red, grey and black porous earthenwares of typical northern composition. As the Erh-li-kang phase of the Shang dynasty ended with the establishment of the capital at An-yang, a little before −1,300, the glazed stoneware sherds from the Upper Erh-li-kang levels appear to date no later than the early -14^{th} century.

The stoneware sherds found at Yüan-chhü showed high levels of mullite and cristobolite in their structures, both typical transformation products from the high-temperature firings of siliceous clays. Little cristobolite forms below 1,100°C, so temperatures well in excess of 1,100°C must have been used to fire the wares.[3] The compositions of the two proto-porcelain sherds, which showed impressed trellis decoration beneath the glaze, appeared characteristically southern to Deng Zequn [Teng Tse-Chhun] and Li Jiazhi [Li Chia-Chih], who believed that: 'they were made in south China, on the basis of their chemical compositions, decoration style and excavation information.'[4]

The compositions of these finds are given in Table 63, together with two further Shang dynasty proto-porcelain glazes excavated from Erh-li-kang (modern Chengchou) itself.

The silica-alumina-calcia-magnesia eutectic mixture can be seen as providing the underlying structure for these glazes. From the very beginning, therefore, Chinese glazes were marching to a different chemical drummer than the ancient glazes of the Near East. Calcia was therefore the prime flux in early Chinese glazes, and the widespread assumption that the calcia present in Shang dynasty glazes came mainly from wood ash was examined by Zhang Fukang [Chang Fu-Khang] in a paper presented

[1] Anon. (1965), Anon. (1975c), Anon. (1976d).

[2] Deng Zequn & Li Jiazhi (1992), pp. 55–63.

[3] Hamer & Hamer (1998) write: 'For the potter the lowest practical temperature for a quartz to cristobolite conversion is 1,100°C (2,012°F). At this temperature a long time is required. Three or four hours soaking at 1,100°C would only convert a small proportion of quartz to cristobolite. At higher temperatures proportionally less time is required.'

[4] Deng Zequn & Li Jiazhi (1992), p. 63.

Table 63 *Late Erh-li-kang period glaze and clay from Yüan-chhü, Shansi province, with two further examples of Shang dynasty glazes, excavated from Erh-li-kang*[a]

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	P_2O_5	MnO	Total
Stoneware clay (Yüan-chhü)	79.7	14.5	0.9	1.8	0.1	0.65	2.7	0.2	0.1	0.02	100.7
Stoneware glaze (Yüan-chhü)	68.0	7.9	1.0	5.4	12.9	1.3	3.1	0.4	-.-	-.-	100.0
Stoneware glaze (Erh-li-kang)	54.6	14.7	1.4	2.6	19.3	2.7	3.5	0.8	1.8	0.3	101.7
Stoneware glaze (Erh-li-kang)	57.7	14.0	0.7	2.9	15.4	2.55	3.9	0.8	1.5	0.3	99.8
1,185°C silica-alumina-calcia-magnesia eutectic mixture[b]	63	14			20.9	2.1					100

[a] *Ibid.*, p. 58, table 2, and Zhang Fukang (1986b), p. 41, table 2.
[b] Singer & Singer (1963), p. 220, table 54.

in +1982 and published in +1986. In this work Chang considered other possible sources of calcia, such as carbonate rocks, shells, fusible calcareous clays, as well as glassy kiln slag, and decided that the phosphorous oxide contents of these various materials were crucial in identifying their use:[5]

Fusible clays contain little or no P_2O_5 . . . shells and limestone contain no P_2O_5 at all.[6] As for kiln slag, although it contains phosphorous, yet the contents in some samples are only 0.3–0.4% . . . the CaO content is also very low . . . Based on the arguments above it seems reasonable to come to the conclusion that the most probable chief ingredient for the Shang dynasty and Zhou (Chou) glazes is wood ash or a mixture of wood ash and clay, while kiln slag, shell and limestone were not used in the Shang dynasty and Zhou period as chief glaze ingredients, although they were extensively used for this purpose in later periods.

APPLICATION

With small sherds bearing thin glazes, such as those from Yüan-chhü, it can be hard to tell whether the glazes are accidental or deliberate. Complete, or largely restored, examples of Shang dynasty glazed stoneware are also ambiguous. The thin glazes on these early vessels can show the characteristic patchiness of fly-ash-glazes, but this could also be due to some sketchiness in the application of deliberate glazes. Convincing examples of naturally ash-glazed wares from the late Neolithic or early

[5] Kiln slag is scraped from the inside walls and fireboxes of wood-firing kilns, but the material has a rather different make-up from prepared wood ash. See Zhang Fukang (1986b), p. 42, tables 3 and 4 for comparisons.
[6] Phosphatic limestones do exist, some with P_2O_5 contents equivalent to wood ashes. However, they are mostly found as thin layers in more substantial limestone beds. Even assuming that they could be identified visually, they would still have needed to have been hand-picked by the potters to supply the consistent P_2O_5 levels encountered in early Chinese stoneware glazes. Pers. Comm. Chris Doherty, Oxford.

Shang dynasty are so far difficult to identify, although it seems likely that the transition from accidental to deliberate ash glazing happened quite rapidly.

WOOD ASH

It may seem odd that a material from an organic source can provide such a useful source of inorganic oxides suitable for glazes, but ash is a very minor product from the burning of wood. Ordinary timber, for example, may only leave some 0.2–0.4% of true ash after burning, with the balance mainly disappearing in the fire's smoke as particulate carbon, water vapour and carbon dioxide.[7] The original sources for these simple compounds are water in the ground, via the tree's roots, and carbon dioxide in the air, absorbed by the tree through the undersides of its leaves. Through the agency of solar energy, tapped by photosynthesis by the leaves' upper surfaces, carbon dioxide and water are built into the long-chain organic molecules needed for the tree's structure and growth, with oxygen being liberated as a by-product of the reactions. When wood is burned the whole process is reversed: arial oxygen is consumed and energy, carbon dioxide and water vapour are liberated.

The small amounts of infusible materials that remain when wood is burned were originally metallic ions in the ground water, drawn up by the tree's roots and exploited in various ways in the tree's cellular structure and biochemistry. As wood burns these elements tend to combine with combustion volatiles to give the carbonates, sulphates, nitrates and phosphates of calcium, magnesium, potassium and sodium, together with some simple glasses where the elements have combined with silica present in the plant material. Carbonates are by far the most abundant compounds in wood ashes but like carbonate rocks wood ashes are conventionally reported as oxide mixtures, using the same oxide-orders as for rocks and clays.

VARIATIONS IN WOOD-ASH COMPOSITIONS

The main variations in wood-ash compositions occur from species to species, although whether the ashes derive from branches, leaves or roots can also be important. Other factors affecting ash-composition may be the seasons of burning, the kind of rocks and earths on which the plants or trees once flourished, and even the ages of the trees or plants themselves.[8] Botanic ash compositions can cover almost as wide a spread as sedimentary rocks, but within this range there are still some characteristic groupings that have served some rather different functions in the history of glasses and glazes.

[7] Tichane (1987), pp. 30–1. Stalks and leaves tend to be richer sources of ash, 2.8–7.2% in the case of stalks, straws, reeds and grasses. In all cases, however, the amounts of ash useable for glazes may be further reduced by 'washing'.

[8] *Ibid.*, pp. 23–7.

Table 64 *Major types of botanic ash used in historical ceramics and glass*

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	P_2O_5	MnO	Total
High-silica ashes											
Rice-hull ash (Japan)[a]	96.0	1.0	0.2	0.04	0.5	0.2	0.9	0.3	0.02	0.2	99.4
Rice-hull ash (China)[b]	94.4	1.8	-.-	0.6	1.0	-.-	1.3 (KNaO)	-.-	-.-		97.8
High-soda ashes[c]											
Usbek	-.-	0.06	-.-	0.04	1.1	2.6	12.3	40.3	0.3	-.-	56.7
Pakistan	-.-	0.2	0.01	0.2	1.6	0.4	9.4	37.3	1.3	0.01	50.4
Iraq	0.5	0.45	0.02	0.3	4.7	12.2	7.0	42.5	-.-	0.02	67.7
Flux-rich siliceous ashes											
Straw ash (China)[d]	80.1	3.25	-.-	1.4	4.9	1.5	5.0	0.6	2.3	0.6	99.7
Fern ash (Ching-te-chen)[e]	74.6	2.9	-.-	1.0	8.5	4.0	5.2	0.1	1.2	1.8	99.3
Sorghum ash (China)[f]	70.8	5.5	-.-	2.5	7.6	3.8	5.9	0.6	1.6	0.3	98.6
High-calcia ashes											
Kiln-site ash, Kung-hsien 鞏縣, Honan[g]	38.7	7.8	0.5	2.0	21.3	1.6	1.7	0.9	-.-	0.1	74.7
Wood ash, Shen-hou 神垕, Honan[h]	20.8	4.1	0.3	1.35	34.1	3.0	3.9	0.3	1.9	0.3	70.1
Common ash (Japan)[i]	31.0	8.9	-.-	3.0	22.4	3.3	3.9	2.3	1.9	1.2	78.0

[a] Sanders (1967), pp. 232–3.
[b] Zhang Fukang (1986b), p. 43, table 4.
[c] Brill (1999), pp. 482–4, table XXIV C.
[d] Zhang Fukang (1986b), p. 43, table 4.
[e] *Ibid.*
[f] *Ibid.*
[g] *Ibid.*
[h] Guo Yanyi (1987), p. 16.
[i] Sanders (1967), pp. 232–3.

Wood- and Plant-Ash Types in Glass and Glaze History

Four types of plant ash in particular have been exploited by potters and glass-makers in West and East Asia: high-silica ashes, high-soda ashes, siliceous ashes that are rich in both potassium and calcium oxides, and high calcia ashes. Typical analyses from these four groups are shown in Table 64.

Highly siliceous ashes were used occasionally as sources of silica in Chinese glazes and sometimes too as refractory materials in later ceramic manufacture, for

example in separating porcelain wares from setters.[9] High-soda ashes derive mainly from the burning of plants grown in hot arid and saline regions that are rich in evaporite minerals. They are central to the history of Near Eastern glasses and glazes, where they often supplied the main alkaline flux.[10] However, most ceramics-producing areas in China are in temperate or in sub-tropical regions where soda-rich plants are rare, so ashes of this style have seen little use in Chinese ceramic history. Flux-rich siliceous ashes have sometimes been used in China,[11] but only occasionally as prime glaze-fluxes. This leaves vegetal ashes that are rich in calcium oxide, and there is good evidence to suggest that high-calcia ashes were the main glaze-fluxes in most high-temperature glazes in south China, from the early Bronze Age until at least the mid +10th century.[12] The importance of calcareous wood ashes in *north* Chinese glazes, made from about the early +6th century onwards, is also now beginning to emerge. Thus the styles of plant life that have adapted to the very different climatic and geological conditions of West and East Asia have also had a profound effect on the course of world ceramic history.

PREPARATION OF ASH

The carbonates of calcium and magnesium that are present in most wood ashes are largely insoluble, while the salts of potassium and sodium that ashes also contain dissolve easily in water. Although these alkaline salts are potentially useful fluxes in glazes, their soluble natures can cause problems in application. For example, soluble compounds tend to make glaze-suspensions caustic, and can also cause glazes to separate during drying, with some alkaline salts crystallising on the glaze-surface. Soluble materials may also find their ways into clay bodies, where they can weaken the clays during firing. When much of the glaze's flux is present in the water of suspension, it can also be difficult to adjust the glaze's consistency (for example, by pouring off surplus water) without affecting its composition. For these reasons potters (unlike glass-makers) have often processed wood ashes in order to remove their more soluble components.[13]

This 'washing' technique can be managed by steeping the ash in water, leaving it for a day or so, and then carefully removing the top water without disturbing the ash-rich sediment. After the discoloured water is removed fresh water is added to the whole mixture, which is then stirred and allowed to settle again. Four or five steepings are usually enough to remove most soluble material, after which the ash can either be used in its liquid ('slop') state, or dried to facilitate storage and accurate

[9] Cheng Zhuhai *et al.* (1986), p. 33.
[10] Rye & Evans (1976), pp. 180–5; Henderson (1985), pp. 274–5.
[11] Wood (1999), p. 191; Wood *et al.* (1999), pp. 32–3.
[12] Zhang Fukang (1986b), pp. 40–5; Guo Yanyi (1987), pp. 11–13.
[13] Glass-makers tend to use vegetal ashes dry and unwashed, an approach that maximises their flux contents, particularly the alkalis, Na_2O and K_2O.

Table 65 *Wood ash from Fukien province, before and after washing*

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	P_2O_5	MnO	loss	Total
Ash (unwashed)	11.95	6.1	trace	0.9	33.6	5.8	10.9	0.2	1.85	2.85	24.4	98.6
Same ash washed	11.0	2.9	trace	0.8	40.5	5.75	2.1	0.1	1.9	2.8	32.2	100.0

weighing.[14] With the first 'washing' the water becomes quite caustic, due to most of the alkalis' dissolving, but less caustic with repeated steeping. Robert Tichane has shown by experiment that about 10% of the ash's weight may be extracted by this process, mostly in the form of soluble potassium salts.[15] In China another method is often preferred, namely placing the wood ash in a densely woven bag, submerging the bag-plus-ash in water, and allowing the alkalis in the ash to diffuse away.[16]

Stoneware potters are concerned with the insoluble fraction that remains, but the alkaline liquor that is removed may be a useful material in its own right, particularly for the dyeing of textiles, such as when indigo has to be suspended in a warm alkaline solution to activate the dye.[17] In Japan ready-washed wood ash for potters was traditionally supplied by the caste who also supplied textiles workers with ash-derived potash.[18]

An indication of how much potash may be lost in washing comes from analyses of mixed wood ash from Fukien province, before and after washing, made by Chen Xianqiu [Chhen Hsien-Chhiu 陳顯求] *et al.* (Table 65).[19]

The authors note:[20]

X-ray analysis identified the major constituent of the wood ash as calcite; no matter whether it was washed or not . . . the phase which contains P_2O_5 may possibly be calcium phosphate.

Wood ash is a rather valuable material and unfortunately is not produced in useful quantities from the firing of stoneware and porcelain kilns, as Père d'Entrecolles noted:[21]

I was surprised to learn that after having fired a hundred and eighty loads of wood in the furnace in one day, that on the next day one finds no ash in the firebox.

[14] A good description of the process, based on early +20th century Japanese practice, occurs in Leach (1940), p. 160. Bernard Leach was one of the first Western writers to show the importance of wood ash in East Asian glaze technology.

[15] Tichane (1987), p. 62.

[16] *Thien Kung Khai Wu*, ch. 7, p. 4b. Sun & Sun (1966), pp. 144–5.

[17] Balfour-Paul (1998), p. 116.

[18] Cort (1979), Appendix B (Shigaraki in 1872), p. 319. The English word 'potash' comes from the practice of evaporating wood-ash-derived liquor in earthenware or iron pots to make crude potassium carbonate, once a substantial industry in Scandinavia and Russia. See Anon. (1877b), pp. 676–7. The word 'alkali' has a similar source, in this case from the Arabic *al kali* meaning plant ash.

[19] Chen Xianqiu *et al.* (1986c), p. 237.

[20] *Ibid.*, p. 237.

[21] Tichane (1983), p. 96, translation of Père d'Entrecolles' letter of +1712.

Thirty to fifty tonnes of short pine-logs might have been a typical consumption for a porcelain kiln when d'Entrecolles was at Ching-te-chen.[22] A combination of the low ash-yield of wood, the fusing of fly-ash to the walls of the kiln and to saggers, and the loss of much fine ash up the kiln's chimney, must account for the phenomenon described above, which is also familiar to modern potters using wood-burning kilns.[23] In most pottery traditions where wood ash has become a significant glaze-ingredient the ash was carefully prepared as a separate material, either by the potters themselves or by their agents (see also pp. 528–9 for a fuller discussion of this issue). In southern China most stoneware was produced in hilly or mountainous areas, rich in unfarmable slopes thick with brushwood and scrub, and this could easily be collected and burned to ash.

PROGRESS IN CHINESE ASH-GLAZES

Stoneware ash-glazes in south China during the Bronze Age seem to have progressed from fly-ash-glazes, to pure ash-glazes, and then to glazes made from mixtures of clay with ash. In the first two cases much of the glaze-substance was supplied by the surface of the wares, as fluxes in the ashes attacked the stoneware bodies at high temperatures. When the ash was mixed with clay, and applied as a creamy clay-ash suspension, the glaze was more complete, so was less aggressive to the wares during firing. In the first example the ash was obviously unwashed as it came straight from the firebox. In pure ash-glazes the use of unwashed ash would have had some advantage as it tends to be more fusible than washed ash. With clay and ash mixtures, however, washed ash would have been preferable for reasons indicated above.

Because the end results of these various approaches tend to be related, both visually and chemically, it is not always easy to tell which technique has been used in a particular example, and from this to construct some sequence of development. Nonetheless the earliest glazes (mainly Shang dynasty) tend to be thin and irregular and apparently applied by brushing. Later Shang dynasty glazes often show obvious 'swags' where a liquid glaze has been applied by dipping or pouring.

Many Western Chou dynasty ash-glazes are thick, often semi-opaque, and frequently applied evenly to both the insides and the outsides of the vessels, and these too show signs of being liquid glaze suspensions, applied by dipping, pouring and brushing. Ceramics of the Spring and Autumn period tend also to be of a similar type but, by the Warring States era, Chinese ash-glazes became thinner and less opaque. During the Han dynasties ash-glazes were frequently applied only to the shoulders and to the inside rims of the vessels; they fade away beneath the fullness of the vessels' forms, and also tend to show a mottled appearance (see Fig. 33).

[22] Hu Youzhi (1995), p. 286.

[23] This phenomenon is known to Chinese potters as 'kiln sweat' (*yao han* 窯汗). In later Chinese glazes there is some evidence for the use of 'kiln sweat', that is the glassy wood-ash slag chipped from the walls of kilns. For examples cf. Anon. (1933), pp. 802–3, and Efremov (1956), p. 494. Kiln sweat tended to be used for more exotic glaze effects, but most Chinese ash-glazes used ordinary wood ash.

Partial Glazing of Han Dynasty Wares

Partial glazing of stoneware in the Han period exploited the potential for stoneware glazes to act as enhancements and accents to ceramic forms. These forms were mainly borrowed from contemporary bronze and lacquer vessels and often bear bronze-like strap handles, or vestigial ring-handles. Parallel horizontal ridges are also a common feature on Han dynasty stoneware vessels, where they serve the double function of evoking a general bronze-like character, and also checking the movement of rather fluid ash-glazes at maximum kiln temperatures, typically some 1,250°C.

The 'fading' glazes that are so common on wares made from the late Warring States period to the late Eastern Han dynasty may have been applied by sifting or sprinkling wood ash over the wares before firing. The round patches of glaze that often occur inside these wares directly beneath their open rims, support this theory.[24] It may be that some organic 'glue' was first applied to the wares in order to encourage the ashes to stick, and a flour-water paste was certainly used for this purpose in medieval English lead-glazed wares, which were glazed by dusting with litharge (PbO) or with galena (PbS).[25]

A rare but occasionally-seen feature of Chinese ash-glazed ceramics of the Han periods are round splashes of thicker glaze, spaced regularly on the shoulders of the vessels, or on the tops of their covers. This style of decoration may have been inspired by the drops of ash-rich glass that tend to fall accidentally on high-fired wares from the inside roofs of wood-fired kiln, as its glassy lining of fused wood ash liquefied at the height of the firing. To copy these 'splashes' ('kiln sweat') intentionally patches of pulverised kiln ash-slag may have been applied to the main glazes before firing.[26]

Taxonomy

Writings in the +20th century occasionally describe Chinese ash-glazes of the Bronze Age as 'feldspathic', a term that dozens of chemical analyses of these early glazes have now shown to be wrong.[27] The description 'lime glaze' is used more often today, but this too has some flaws, as it seems to imply some use of calcium hydroxide in the glaze. However 'lime' in the broader sense of describing calcium oxide is a useful term and has been adopted in most Western and Eastern writings on the subject. One advantage of 'lime glaze' is that it does not infer the use of wood ash in the glaze recipe, which is helpful as many later high-calcia glazes used in China, have limestone rather than wood ash as their prime glaze-flux. 'Lime glaze'

[24] Wood in Ayers *et al.* (1988), p. 31.
[25] Newell (1995), pp. 77–88.
[26] An example from the Museum of Chinese History, Peking, is illustrated in Wood (1999), p. 23; another is shown in Satō (1981), p. 24, pl. 29.
[27] Luo Hongjie's Chinese glaze database (1996) contains some 200 pre-Sung greenware glazes, all calcareous in composition.

is also useful for distinguishing early calcia-rich glazes from the later 'lime-alkali' glazes, where much of the glazes' calcia was replaced by potassium and sodium oxides. Both 'lime' and 'lime-alkali' will be used in this book.

The Nature of Early Chinese Stoneware Glazes

High-temperature glazes in Bronze Age China seem to have been natural developments from the gradual rise in firing temperatures used with some Neolithic earthenwares, which in turn was made possible by the refractory natures of many southern surface clays. The extensive use of botanic ash in these glazes had been anticipated by West Asian glass and glaze technology, but the employment of *calcareous* ashes in China was a novel approach and one that created compositions in the region of the silica-alumina-calcia-magnesia eutectic mixture. This set the earliest Chinese glazes well apart from the soda-rich earthenware glasses and glazes of the Near East, which were also distinguished by their use of strong colour from the deliberate additions of rare-element compounds. What early Chinese ash-glazes lacked in colour, however, they made up for in the toughness of their surfaces, enhanced by the superior strengths of their stoneware clays. This means that many early Bronze Age glazed vessels from China survive complete and unweathered, in much the same states as when they were drawn from the kilns. By contrast, early Near Eastern glazed ceramics that are still in their original conditions are considerable rarities.

Southern High-Potassia Glasses and Glazes

While the vast majority of early Chinese high-temperature glazes appear to have been made from calcareous ashes mixed with siliceous clays, and to have arisen from technologies quite separate from any known glass-making traditions, there remains a single puzzling example of a high-potassium glaze on a Western Han dynasty vessel from Hunan province.[28] This glaze has some affinities with contemporary high-potassium glasses from the same period that have been excavated in south China, and also to glasses from the important Arikamedu site in southern India (Table 66).

This rare southern alkaline glaze seems the first example of a high-potassium glaze identified in China's ceramic history, and it anticipates the compositions of similar, but very much later, Chinese *fa-hua* 琺華 glazes by more than 1,000 years.[29] It raises the question of what relationship it might bear to the high-potassia glasses, also found in southern China, objects that are discussed in more detail on pp. 625–7.

[28] Newton (1958), pp. 13–14.

[29] Wood *et al.* (1989), pp. 171–82. *Fa-hua* is the term for coloured glazes that are enclosed within raised, containing borders of slip. The technique resembles cloisonné enamels, in which coloured enamels laid on to metal bodies are encased in wire 'cloisons'. See also pp. 501, 512 and 628–31 of this volume.

Table 66 *Glasses excavated at Han dynasty sites in south China, compared with Arikamedu glass, and high-potassia vessel-glazes from south China*[a]

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	CoO	PbO	CuO	SnO_2	Total
Blue bead from Kuangtung province, Western Han	72.0	3.4	1.65	1.4	1.3	15.3	1.5	1.5	0.05	-.-	0.1	-.-	98.2
Blue bead from Kuangtung province, Western Han	71.7	4.8	1.6	0.7	0.4	16.4	0.35	1.4	0.03	-.-	-.-	-.-	97.4
Blue bead from Kuangsi province, Western Han	74.7	3.0	1.35	0.6	0.3	15.5	0.2	1.7	0.06	-.-	-.-	-.-	97.4
Han mid-temperature glaze from Chhang-sha 長沙[b]	75.8	6.9	1.9	1.6	0.4	9.7	2.1	-.-	-.-	-.-	0.7	-.-	99.1
Blue drawn glass tube from Arikamedu[c]	77.0	2.1	1.9	2.2	0.4	13.3	0.6	1.7	0.15	0.06	0.04	0.01	99.5
Blue flat fragment of cullet, Arikamedu[d]	73.8	1.8	2.3	1.15	0.3	16.5	0.34	3.0	0.07	0.02	0.03	0.006	99.3

[a] Compiled from Zhang Fukang (1986b), pp. 93–4, tables 2 and 3; Shi Meiguang *et al.* (1987), p. 18, table 2; Brill (1999), pp. 141, 337, table XIII E (Arikamedu); and Wood *et al.* (1989), p. 174, table 1.

[b] Newton (1958), p. 14.

[c] Brill (1999), pp. 141, 337, table XIII E (Arikamedu).

[d] *Ibid.* These two blue glasses are '1st century AD or later'.

In terms of essential technology, modern glass scientists propose the most likely flux for these unusual high-potassium glasses would have been saltpetre (potassium nitrate, KNO_3), or recrystallised potassium carbonate from vegetal ash. This judgement is made because their low sodium and magnesium oxide levels seem to rule out the direct use of wood ash; the usual source of potassia in Western glasses, particularly the ash-based 'forest glasses' of northern Europe, which also tend to be rich in potassium oxide.[30]

As to the high-potassia *glaze* found on one Western Han vessel from Chhang-sha, and reported by Isaac Newton in +1958, the evidence here is ambiguous. Its composition is certainly similar to some glasses found in south China, but apparently with some clay additions, perhaps to raise firing temperatures and to assist in application to the wares. There is also a possibility, however, that the glaze has no relation to glass at all but is essentially a high-potassium wood-ash slag, or an ash from a siliceous material such as rice-straw or fern, applied before firing. A superficial impression is that the glassy patches seen on vessels of this type may represent a spontaneous build-up of fly-ash at high temperature within the kiln. But the glassy areas tend to appear on similar places on many examples, such as near to the handles on three-legged vessels of *ting* 鼎 form, derived from local bronze styles.[31] This seems to suggest deliberate application of the glaze before firing, rather than a fortuitous effect within the kiln. Another factor is the presence of copper oxide in this particular glaze. Copper colourants are typical of early glasses, but unknown in natural wood-ash compositions (Table 67).

GLAZED CERAMICS FROM VIETNAM

This particular style of south Chinese ceramic was taken up in northern Vietnam, when the country became part of the Eastern Han dynasty empire. Links with glass are possible here too, and should perhaps be considered. Some examples bear whitish glazes with occasional thick green glassy splashes that appear superficially like 'kiln sweat' but which are actually deliberately applied.[32] The one example analysed to date is a rather pale-bodied vessel of tripod form, without green splashes. It bears a translucent glaze that shows a composition different from both contemporary south Chinese ash-glazes and the rare high-potassia glaze described above.[33]

The Vietnamese glaze is rich in alkalis, particularly sodium oxide, and it is not impossible that this glaze was made from a combination of igneous rock with wood ash, rather in the manner of later Japanese feldspathic glazes.[34] However, the same oxide-balance could also be explained as representing a mixture of powdered glass and body-clay. Some non-potassic glasses from India and Vietnam tend to be rich

[30] Shi Meiguang *et al.* (1987), p. 19. Henderson (1985).
[31] Mino and Tsiang (1986), pp. 62–3.
[32] Stevenson & Guy (1997), pp. 172–5, pls. 7–14.
[33] Desroches (1989), pp. 36–8.
[34] Faulkner & Impey (1981), p. 2; Vandiver (1992), pp. 224–5, table 1.

Table 67 *High-potassia glaze from Hunan province compared with high-potassia Chinese glass and natural wood-ash slag from a Chinese kiln*

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	CuO	Total
Han mid-temperature glaze from Chhang-sha, Hunan[a]	75.8	6.9	1.9	1.6	0.4	9.7	2.1	-.-	-.-	0.7	99.1
Eastern Han glass from south China[b]	78.1	3.3	1.25	-.-	0.7	13.8	1.6	1.5	-.-	-.-	100.3
Low-calcia wood-ash slag from a Hu-thien 湖田 kiln, Chiangsi[c]	78.7	10.8	3.9	1.1	0.9	3.5	0.4	0.2	0.3	0.01	99.8
Rice-straw ash[d]	75.8	2.1	0.5	5.8	2.6	6.7	1.45	0.6	4.7	-.-	100.5
Fern ash[e]	74.6	2.9	1.0	8.55	4.0	5.2	0.1	1.8	1.2	-.-	99.4
Sorghum ash[f]	70.8	5.5	2.5	7.6	3.85	6.0	0.6	0.3	1.6	-.-	98.8

[a] Newton (1958), p. 14.
[b] Shi Meiguang *et al.* (1987), p. 18, table 2.
[c] Zhang Fukang (1986), p. 48, table 4.
[d] *Ibid.*
[e] *Ibid.*
[f] *Ibid.*

Table 68 *Eastern Han dynasty cockerel-headed three-legged vessel, glaze and body. Excavated at Thanh-hoá, H: 15 cm. Also a lower-potassia Indian glass of the same period, and a 50:50 mix of both materials*[a]

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	Total
Eastern Han glaze, Vietnam	71.2	10.8	1.2	2.0	3.8	0.9	3.75	6.2	0.2	100.1
Eastern Han body, Vietnam	78.9	14.85	2.5	1.6	0.1	0.1	1.15	0.6	0.03	99.8
Indian lower-potassia glass	67.0	6.1	0.25	2.2	3.2	2.0	3.8	13.4	0.6	98.6
Glass and vessel-body 50:50 mix	72.9	10.5	1.4	1.9	1.65	1.05	2.5	7.0	0.5	99.4

[a] Desroches (1989), pp. 36–8 and Brill (1999), p. 333, table XIII.

Table 69 *Analyses of Bronze Age blackware glazes from Chiangsi province (c. –10th century)*[a]

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Total
Glaze, Chhing-chiang	68.5	12.2	1.25	9.0	0.9	1.8	5.1	0.8	0.5	0	100.1
Glaze, Chhing-chiang	61.0	17.7	1.3	6.9	4.6	2.2	4.3	0.5	0.9	0.6	100.0
Glaze, Ying-tan	61.5	16.8	1.25	10.1	1.7	1.9	5.7	0.6	0.2	0.2	100.0
Glaze, Ying-tan	61.7	18.0	1.0	5.0	4.5	1.7	7.4	0.5	0.05	0.2	100.1

[a] Luo Hongjie (1996), database.

in both sodium and aluminium oxides, and also low in lime.[35] Equal-parts mixtures of some of these glasses with the kinds of siliceous stoneware clays used for the tripod-vessel could have supplied similar glazes to that found on the Eastern Han dynasty vessel (see Table 68). More data are needed from this area before the real natures of these glazes can be properly assessed.

Finally, to complete this review of exceptions to the general calcareous wood-ash-plus-clay principle that operated in Bronze Age glazes in south China, mention should be made of some unusual high-iron glazes excavated from Chiangsi province, and dated to the period –1,200 to –800.

Bronze Age Blackware Glazes

Some of the very earliest blackware glazes so far found in the country have been found at the villages of Ying-than 鷹潭 and Chhing-chiang 清江 in Chiangsi province (south-east and south-west of Pho-yang lake 鄱陽湖). They date from the late

[35] Brill (1999), p. 333, table XIII.

Shang to the Western Chou period and differ from the general run of Chinese Bronze Age glazes in their unusually low lime contents. Their potassium oxide contents proved surprisingly high, and the glazes also showed iron oxide levels in the 5–10% range, enough to render them completely black (Table 69). It is possible that these glaze compositions were made by mixing iron-rich clays with alkali-rich wood ashes, although the use of pulverised igneous rocks in the original recipes may be another explanation for their high potassium levels.

These anomalies apart, stoneware glazes made from clay and ash mixtures dominated the history of Chinese glaze manufacture for centuries. This essentially south Chinese approach can be regarded as one of the most successful solutions to glaze construction in China's entire ceramic history, and formed the basis for stoneware manufacture there for more than 2,000 years.

COLOURED GLAZES, GLASSES AND LEAD GLAZES

COLOUR AND TEXTURE IN EARLY CHINESE AND NEAR EASTERN GLAZES

The grey-green, brown, amber and olive colours typical of China's early ash-glaze tradition came mainly from iron oxides in solution (Fe^{2+} and Fe^{3+} ions), with some modifications by titanium and manganese ions. These colours derived from the 'impurities' in the glaze raw materials, and were therefore less advanced in their technology than the well-controlled near-primary colours achieved in Near Eastern glass. Even before Chinese glazes began to develop, glass-workers from Egypt had devised turquoise-blue and sealing-wax red glasses by adding various amounts (0.5–8.0%) of copper oxides to their basic clear glasses.[36] These two colours were soon joined in the Near East by a white from calcium antimonate, a yellow from lead antimonate, and a royal blue from cobalt oxide.[37] The microcrystalline (and therefore opaque) copper-red and antimony-yellow glasses were sophisticated effects as the former needed careful reduction to develop microcrystals of red cuprite (Cu_2O), while lead antimonate (Pb_2SbO_7) was a compound probably developed through the thermal combination of lead and antimony ores.[38] This vital difference in approach (that is, the deliberate colouration of glazes with scarce metal oxides) distinguishes Near Eastern from East Asian glazes in the -2^{nd} millennium, and is emphasised by Table 70.

Near Eastern copper-turquoise glazes tend to be transparent, as do cobalt-blue glazes from West Asia. Antimony-yellow glazes, however, are nearly always opaque, or at least turbid, while copper-red glasses are variously opaque and translucent. Very early Chinese stoneware glazes are sometimes transparent, but are more often matt and microcrystalline. Such significant differences in opacity in association with glaze colour deserve some explanation, as in many cases they derive from the natures of the colouring oxides themselves.

The two simplest types of glaze colour are those that are transparent and those that are opaque. With transparent coloured glazes the colouring oxides have dissolved totally in the liquid glaze at full temperature, and have remained completely

[36] Barag (1985), p. 122; Henderson (1985), pp. 281–2.

[37] Rooksby (1962), p. 26. Rooksby (also p. 26) notes that the white opacifier calcium antimonate in these early glasses usually takes the form $Ca_2Sb_2O_7$, but can sometimes appear as $CaSb_2O_4$. Mixtures of calcium antimonate with cobalt oxide produced opaque rather than transparent blues.

[38] Rooksby (1962), p. 23, writing on antimony-yellow glasses from early Egyptian (*c.* −1,450) to Roman times writes: 'It may be concluded that such glasses were made by adding antimony oxide (probably as stibnite) to the other constituents which yield a lead-alkali-silicate medium on melting. During the firing process a reaction was promoted between the antimony oxide and the lead-oxide constituent to form some $Pb_2Sb_2O_7$, which remained incompletely dissolved in the glassy matrix and conferred to it an opacity and yellow colour.'

Table 70 *Elemental abundance in igneous rocks of colourants used in –2nd millennium glasses and glazes*[a]

Colourants in Chinese glazes (Present naturally in the glaze raw materials) (% wt.)			Colourants in Near Eastern glazes and glasses (Deliberate additions to the glazes or glasses) (% wt.)		
Iron	Fe	5.0	Copper	Cu	0.007
Titanium	Ti	0.44	Antimony	Sb	0.01
Manganese	Mn	0.1	Cobalt	Co	0.004

[a] Kaye & Laby (1957), p. 111.

dissolved in the glass or glaze through cooling. In this case, the constituent atoms of the colourant material (some metallic element with oxygen) have separated within the glassy matrix while remaining in electrostatic association. Thus iron atoms give transparent yellow and amber colours when in the form of Fe^{3+}, while bluer solution colours tend to occur where Fe^{2+} ions are abundant, but with some Fe^{3+} still present (glazes with Fe^{2+} alone are thought to be colourless). These colours are seen by transmitted light, i.e. light that has passed through the glaze before it is reflected back again, through the glaze thickness, from the clay–glaze interface. In a similar way, transparent glazes coloured by copper contain the oxide in the form of dissolved Cu^{+} ions. These give turquoise-blue solution colours to high-soda glazes and emerald-green colours in high-lead glazes, again by means of light that has passed through the glaze before it has been transmitted back from the clay surface itself. Obviously, with transparent coloured glazes, the clays need to be light in tone in order to maximise the quality of the solution colours, and generation of the whitest possible ground has always been an important issue in ceramic traditions where colour from transparent glazes has been exploited.

Pure opaque glaze-colours, by contrast, do not necessarily need light clay backgrounds, as the light tends not to reach the clay surface, but is reflected from coloured crystals suspended within the glaze itself, i.e. the colour derives from *suspension* rather than from *solution* effects. Two examples of this phenomenon are the fine opaque yellow glazes supplied by crystals of lead antimonate ($Pb_2Sb_2O_7$), and the sealing-wax red glasses coloured by crystals of cuprous oxide (cuprite Cu_2O), both of which render the glazes opaque, but still brightly coloured. In some cases these micro-crystals have remained undissolved from the original glaze-batch. More often they have dissolved at higher temperatures, and then recrystallised in cooling, a consequence of the fact that liquids can dissolve much more material at high than at low temperatures, with the difference crystallising out as the liquid cools.

Between these two extremes of transparency and opacity are found glazes that show translucent colours. These glazes are neither obviously transparent nor obviously opaque, and the clay body can often be sensed beneath the glaze. Translucent glazes contain suspended material, and this can be of a colloidal fineness, lying

somewhere between solution and suspension. Some early Near Eastern copper-red glasses are of this type, where minute crystals of pure copper metal develop within the glass during cooling. The copper crystals contain only some dozens of atoms apiece, with the individual crystal-sizes often falling within the nanometre range,[39] and therefore colloidal in character.[40] Related to this effect are the unusual 'glass emulsion' glazes. These contain minute spherules of suspended glass, rather than small mineral or metal inclusions, and are sometimes known as 'liquid–liquid phase-separated glazes'. These contain fine glassy spherules that have separated from the main glazes during cooling. Glass-emulsion glazes of this style often show milky-blue or milky-white translucency through light interference effects, related to Rayleigh scattering.[41]

In the cases described above, materials within the glazes supply definite colours to the glassy matrices, but it also happens frequently that the minerals that crystallise within a glaze during cooling are colourless, and supply only opacity, translucency or some kind of surface texture to the glazes. Good examples of this latter phenomenon in high-temperature glazes of the early East Asian type are anorthite (lime feldspar, $CaAl_2Si_2O_8$) and wollastonite (calcium metasilicate, $CaSiO_3$). These two lime silicates tend to give silky, stony or waxen textures to the glazes, as their minute crystals scatter and reflect light within the glaze-thickness. Other sources of glaze quality and texture that are largely colourless are undissolved glaze-batch materials (which can act as 'seeds' for true mineral crystallisation to occur at full temperatures or in early cooling) and bubbles. Fine or coarser bubbles, often derived from carbonate and phosphate decomposition, are also common within glazes fired at higher temperatures, and these can create clouded effects that are rather jade-like. Bubbles may also be 'squeezed' into molten glazes at high temperatures from pores within the shrinking and vitrifying clay bodies, and these too help cloud or veil glaze-transparency.

This list is far from complete, but it does highlight some major mechanisms for the production of colour and texture within ceramic glazes. In practice, however, the effects become more complicated when a number of these phenomena occur together, as they often do in Chinese glazes. Thus glazes coloured with dissolved ferrous iron (Fe^{2+}) may have their colours rendered yellower by titania ions, and their qualities modified by microcrystals of anorthite, to give a sugary green texture. Likewise oxidised glazes made milky and opaque by liquid–liquid phase separation may further be solution-stained green by Cu^{2+} ions, to supply milky-green effects. Sometimes too an excess of colouring oxide may give solution and suspension

[39] A nanometre is one-millionth of a millimetre.

[40] Freestone & Barber (1992), p. 58, note that colloidal effects from copper, gold and silver in glasses usually rely on metal particles less than 50 nanometres in diameter, and typically between 20–40 nanometres across. Glazes, being much thinner, can accommodate copper crystals in the 200–300 nanometre range and still not be opaque, as Freestone & Barber found in a Chhing dynasty copper-red glaze. They add that, 'It is unlikely that a glaze that contained a higher density of metal particles of this size, or that was significantly thicker, would produce such a pleasing red.'

[41] Discussed in greater detail on pp. 534–5 and 596–7.

colours within a single glaze. Thus the colours of Tzhu-chou 磁州窯 red enamels may contain both yellow and red components from ferric oxide: the yellow from Fe^{3+} ions in solution, and the red from discrete crystals of hematite (Fe_2O_3), that have either remained undissolved in the glaze, or have recrystallised in cooling. Thus multiple causes for qualities of colour and texture tend to operate in Chinese glazes, and these various phenomena may need sophisticated micro-structural and compositional analysis to identify, separate and illuminate their various causes.

Oxidation and Reduction

No discussion of glaze colour can be complete without some reference to oxidation and reduction (see p. 296). Their effects are particularly important with Chinese glazes, as Chinese ceramic technology has made more effective use of deliberate variations in kiln atmospheres than any comparable world ceramic tradition. The outcomes of reduction processes can be dramatic. Iron-containing glazes, for example, may fire ivory-cream in oxidation and a cold blue in reduction, while copper-containing glazes may be bright green in oxidation and a true red in reduction. Clays too can show clear and obvious differences according to whether they have been oxidised or reduced. The most familiar effects occur with iron-rich clays (typically those with some 5–10% iron oxides) that fire orange-red in oxidation and a cool grey in reduction.

With glazes, reduction has to take place before they melt, as molten glass is rather impervious to reducing gases. With clays, however, oxidation states may be altered at any stage of the firing, above about 600°C. For this reason, with wares such as Neolithic grey wares and the terra-cotta warriors, reducing conditions were maintained both through firing and early cooling. This practice is followed in China today, for the production of grey-firing bricks and tiles.

Titania in Chinese Glazes

A final, but vital, contributor to colour in glazes (particularly those of China and other East Asian ceramic traditions) is titanium dioxide, a ubiquitous material in upper crustal rocks where TiO_2 makes some 1.05% of their weight.[42]

In Part 2 the significant presence or absence of titania was mentioned regularly as a deciding factor between ordinary high-firing clays (stonewares) and the much whiter materials (porcelains), with white porcelains tending to be particularly low in titanium dioxide. In glazes too, titania often has a similar and decisive effect on quality. Ordinary high-temperature glazes are rich in the material, while the finest Chinese glazes, used on both stoneware and porcelain, tend to show low-titania compositions.

Titania is important in glazes because of its powerful yellowing effect on iron colours in solution (that is a combination of Fe^{2+} with Fe^{3+}). Titania's effect was

[42] Gilluly *et al.* (1960), p. 512, table 3.

studied by the Japanese ceramic chemist Ishii Tsuneshi in the late +1920s when he noted a change from 'indigo blue to yellowish-brown' when 0.05 to 0.7% rutile (a rich source of titania) was added to a standard bluish Chinese-type celadon glaze. The sequence established by Ishii ran:[43]

0.05–0.1% TiO_2 still blue; 0.2–0.3% TiO_2 grass-green; 0.3 to 0.4% TiO_2 yellowish-green, and 0.5 to 0.7% TiO_2 a deep yellowish-brown.

LOW-FIRED GLAZES, GLASSES AND 'GLASS-PASTE' IN CHINA

While Chinese stoneware glazes seem to have developed quite independently from any Western influence, *low-fired* glazes in China seem initially to have been inspired by imports of Western faience and glass. So far, the earliest objects resembling Near Eastern faience that have been excavated in China are a number of small greenish quartz-bodied beads, found in Pao-chi and Fu-feng counties of Shensi province, about 120–150 kilometres west of Sian, and dated to an early Western Chou (–11th to –10th centuries) context. Because of the unusually high potassium levels found in these beads' interstitial glasses they have been proposed as being possibly Central Asian, or even Chinese, in origin.[44] However, the main author of this proposal (Robert Brill) modified his opinion in +1991 when his isotopic analyses of a trace of lead in one of these faience beads plotted near to an area already established for Egyptian lead ores.[45] At present, the origin of these beads remains unresolved, and similar high-potassia faience beads found in Honan province, and dated to the Spring and Autumn period, are also of unknown provenance.[46]

The next important group of Chinese finds showing Western influence occurs in the numerous Chinese eye-beads, made from both glazed ceramic and glass, that are usually dated to the Warring States period[47] (see also discussion on pp. 478–80, 614–15). These seem to imitate a glass-bead style that originated in the Near East as early as the mid –2nd millennium. Their production spread gradually to the eastern Mediterranean, and then further eastwards to Central Asia.[48] In Near Eastern polychrome eye-beads successive drops and trails of coloured glass were treated by flame-work and marvering to create multi-coloured concentric rings on the beads' surfaces.[49]

[43] Ishii Tsuneshi (1930a), p. 357. Vandiver & Kingery (1986a), p. 221, also note: 'The green, which is caused by iron oxide, looks olive if titanium dioxide is present in small quantities . . . The iron and titanium associate so that the structure around the iron is not symmetrical, which changes its interaction with light to absorb more in the red and less in the yellow band of visible light.'

[44] Brill *et al.* (1989), p. 13; Brill (1991), pp. 116–18.

[45] Brill *et al.* (1991), p. 118, call the bead's association with Egyptian lead isotope analyses of samples from the 12th to the 18th dynasties: 'close, but not really close enough to be a match . . .'

[46] Zhang Fukang *et al.* (1986), pp. 91–9.

[47] Yoshimizu Tsuneo (1989), pp. 52–4.

[48] *Ibid.*, pp. 19–51.

[49] *Ibid.*, see particularly picture-sequence p. 55. Marvering is a glass-maker's term for rolling hot glass on to a (usually) metal plate. In the case of the beads it flattens added glass details into the background glass. The same effect can also be achieved with flame-work, i.e. applying a flame locally to applied glass to melt it into the background. It is not always easy to see which method has been used, and sometimes both can be used on one piece.

The various coloured glasses used for the beads from West Asia were still soda-lime silicates, although small amounts of lead oxide appear in analyses of the opaque yellow glasses coloured with antimony.[50] It seems that the importation of these Near Eastern and Central Asian coloured glass artefacts prompted China's first essays in glass technology, together with China's first experiments with low-temperature glazes.

The first true glasses in China tend to be dated to early in the Warring States period, and their compositions differ from both the typical soda-lime silicates of West Asia, and the mysterious potassia-rich faience beads found in Shensi and Honan provinces.[51] Nonetheless, there does appear to be a broad compositional connection between these early Chinese glasses and an uncommon type of ancient Near Eastern high-lead glass, coloured bright red with cuprite (Cu_2O) crystals. These red glasses occur as early as the -8^{th} to -4^{th} centuries at sites such as Nimrud and Tabrak Kale in Mesopotamia, and they contain levels of lead that are far higher than any of the soda-lime types (Table 71).

These rather specialised Near Eastern glasses used their high lead levels to encourage large cuprite crystals to develop in cooling and/or in striking, to produce bright and waxy copper-red colours.[52] The antimony was probably introduced to encourage the same effect via redox reactions within the solid glass, again during the cooling or striking stages, rather than operating as a separate glass colourant.[53]

Despite these superficial compositional similarities, the first Chinese glasses differ from red Mesopotamian glass in some important ways. Most significant is the high baria (BaO) content of the Chinese material, which came to characterise Chinese glasses for hundreds of years, mostly at levels from about 5–15% BaO in the glass-matrix.

A sophisticated manipulation of redox effects is also characteristic of much glass from West Asia, but apparently absent from its Chinese equivalent, which also shows a far more restricted colour-range. Typical early Chinese glass colours were white (produced by a host of small bubbles and fine barium disilicate crystals), greenish white, turquoise-blue from copper, a purer blue from cobalt, and dark amber and black from iron.

In the Warring States and Han periods the similarity between Chinese glass and jade was exploited by using glass as a jade substitute for important objects such as *pi* 璧 discs and for jade burial suits.[54] A rare example of glass containing cobalt oxide

[50] Rooksby (1962), p. 26.

[51] Gan Fuxi (1991), p. 2; An Jiayao (1996), pp. 127–30.

[52] 'Striking' is the process of reheating glass to encourage nucleation of colouring phases, which might be in the form of cuprite or minute crystals of metallic copper, silver or gold. Freestone (1987), p. 188, writes: 'Lead oxide had the effect of increasing the size of the cuprite particles and reducing the tendency of the glass to devitrify.'

[53] 'Antimony and/or iron oxides are often present [in Near Eastern copper-red glasses] and promoted the formation of cuprite when the glass was struck.' Freestone (1987), p. 188.

[54] Fenn *et al.* (1991), pp. 59–60.

Table 71 *High-lead Mesopotamian copper-red glasses of the –1st millennium compared with early Chinese glasses of the Warring States period*[a]

Site	Date	SiO_2	Al_2O_3	Fe_2O_3	Cu_2O	CaO	MgO	K_2O	Na_2O	Sb_2O_3	PbO	BaO	Total
Near Eastern cuprite-red glasses													
Nimrud	-4^{th} C	42.3	0.7	0.4	8.6	3.8	2.8	1.4	9.5	4.2	25.0	-.-	98.7
Tobrak Kale	-8^{th} to -6^{th} C	41.1	0.6	0.5	11.0	3.0	2.2	2.15	9.1	3.9	23.5	-.-	97.1
Early Chinese glasses													
Green-blue glass bead	-5^{th} to -1^{st} C	41.4	0.9	0.3	2.1	1.4	0.6	0.2	5.9	0.05	37.4	9.7	100.0
Colourless glass bead	-4^{th} to -1^{st} C	51.3	0.5	0.1	-.-	0.4	1.5	0.1	6.1	0.05	28.3	11.4	99.8

[a] Freestone (1987), p. 176. Brill *et al.* (1991), pp. 49–52, table 1.

(a glass eye-bead) has been found in a Spring and Autumn context in China, but the soda-lime nature of the glass, and the presence of arsenic and antimony in the bead's white pattern, all indicate that the object may be a Western import.[55]

Whether any technological transfer occurred from the Near East or Central Asia to China to stimulate early Chinese glass-making is still an open question. On the plus side there is the generous use of lead oxide in both traditions, together with the fact that Chinese glass-makers were imitating glass artefacts from West Asia, so may well have tried to discover how they were made. On the debit side lead-bearing Near Eastern red glass was a minor product in a tradition dominated by soda-lime compositions. The Mesopotamian red glasses themselves appear to be soda-lime glasses, modified with lead oxide, to which some sources of copper and antimony have also been added. The Chinese glasses are more in the nature of lead-baria silicates, with the ancillary fluxes (Na_2O, K_2O, CaO and MgO) at generally lower levels. But perhaps the greatest difference between the two traditions lies in this substantial presence of baria in early Chinese glass. That compositional feature has generated much speculation on how deliberate or otherwise the use of this heavy-metal oxide was in the manufacture of Chinese glass.

BARIUM IN EARLY CHINESE GLASS

It seems possible that the 5–15% BaO typically present in early Chinese glass was introduced by the lead ore that supplied the lead oxide in the glass-batch, as many examples of lead sulphide ores contain barium compounds as associated minerals.[56] However, the Pb:Ba balances in these glasses do not suggest the use of any specific lead-barium ore, nor do they imply that the lead oxide and baria were manipulated in such a way that the lead oxide was used to replace the barium oxide, or vice versa. Robert Brill and colleagues established these points in a study of eighteen Chinese glass samples from the -5^{th} to the -1^{st} centuries:[57]

> The PbO and BaO do not appear to correlate either positively or negatively when the entire group of 18 samples is considered. This implies that these oxides are not associated with one another as a single batch ingredient of uniform composition and neither are they related substitutionally; that is they were not introduced as two separate uniform materials, such that when the percentage of one increased the other would automatically have decreased.

[55] Zhang Fukang *et al.* (1986), p. 97 (see also Plate II, b4–1, same vol.).

[56] Associations of lead with barium ores are common. For example, a wartime survey of barium minerals in England and Wales found that half the barium occurrences were in lead mines. The Force Crag Mine, 11.5 kilometres south-west of Keswick was typical: 'The mine has had a somewhat chequered history partly due to the fact that the vein contains galena, blende and barytes and that the two latter minerals are not separable except by hand picking or flotation.' Dunham (1945), p. 94.

[57] Brill *et al.* (1991), p. 35.

Brill also discounts use of the commonest natural source of barium, barite (barium sulphate) as a possible ingredient in these glasses, after trying to duplicate a typical early Chinese glass with the composition: 45% PbO, 14% BaO, 38% SiO_2 and 3% Na_2O:[58]

> Using barium sulphate as an ingredient, a poorly melted glass filled with much unreacted barium sulphate resulted, even after being soaked at 1,200°C for six hours. On the other hand, using barium carbonate produced a well-melted transparent, homogeneous glass. Therefore we believe that Chinese glass-makers, instead of using barite as a raw material, are much more likely to have used witherite, the mineral form of barium carbonate.

Nonetheless, these observations do not prove that Chinese glass-makers of the Warring States period were familiar with barium compounds as separate minerals, as they may have used lead ores containing varying amounts of barium carbonate.

CHINESE 'STONEPASTE' BEADS

The various elements of a complex story (imported eye-beads, Chinese glass, and Chinese copper-barium-silicate pigments (see pp. 474–7)) all combine in an unusual group of Chinese-manufactured eye-beads that appeared early in the Warring States period. These are significant objects in the history of Chinese ceramic technology as they bear a set of coloured glazes or glasses applied to a pale stony material, and are a distinct and separate production from contemporary Chinese beads made solely from glass. They have been excavated from tombs such as that of the Marquis of Tseng 曾侯, dated to the -5^{th} century.[59] A detailed study of one example of this bead-type was made recently at the British Museum's Department of Scientific Research.[60] This bead was made in a style that Peter Hardie has associated particularly with:[61]

> fine glass beads found in Chu [Chhu] 楚 tombs dated between 399 and 350 BC at Yiyang [I-yang] 益陽 . . . and is one of those designs found only in opaque glass (originally coloured turquoise, red, yellow and white) over a core of imperfectly fused glass frit.

The Chinese glazed bead examined at the British Museum was microsampled and then studied by scanning electron microscopy and microprobe analysis, while X-ray diffraction was used to confirm the presence of certain minerals. This study produced some unusual results:

The bead body. The pale-grey vitreous body beneath the glazes showed a composition unlike any Chinese ceramic or glass material so far examined. The only parallels that could be found to this material were ashes from fast-growing plants with tough siliceous stems, such as rice, fern or sorghum. The Warring States bead may therefore be a rare example of a ceramic body made entirely from fused plant ash, in this case a vegetal ash of the flux-rich siliceous type (Table 72).

[58] *Ibid.*, p. 34.
[59] Yoshimizu Tsuneo (1989), pp. 53–4. Rawson (1992), p. 260, pl. 190.
[60] Wood *et al.* (1999), p. 32, table 3.
[61] Anon. (1981b), pl. 12 no. 6, shows a tubular glass eye-bead; cited in Hardie (1993), p. 67.

Table 72 *Eastern Chou dynasty bead body compared with flux-rich siliceous ash*

	SiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	BaO	PbO	P_2O_5	Total
Bulk body of Chou bead[a]	66.2	3.4	1.4	0.3	5.4	7.5	1.7	4.8	0.3	4.3	4.7	100.0
Bulk bead-body less PbO & BaO	66.20	3.4	1.4	0.3	5.4	7.5	1.7	4.8		-.-	4.7	100.1
Above normalised*	69.40	3.5	1.4	0.3	5.7	7.8	1.8	5.00				99.8
Rice-straw ash[b]	75.8	2.1	0.5	0.6	2.6	5.8	1.45	6.7	4.8	-.-		100.4
Sorghum ash (China)[c]	70.8	5.5	2.5	0.3	3.85	7.6	0.6	6.0	1.6	- -		98.8
Fern ash (Ching-te-chen)[d]	74.6	2.9	1.0	1.8	4.0	8.55	0.1	5.2	1.2			99.4

* The barium oxide and the lead oxide are assumed to have diffused into the bead-body from the glazes.
[a] Wood *et al.* (1999), p. 32, table 3.
[b] Zhang Fukang (1986b), p. 43.
[c] *Ibid.*
[d] *Ibid.*

Table 73 *Eastern Chou dynasty bead glazes*

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	BaO	PbO	P_2O_5	CuO	Total
Red glaze	42.3	2.0	<0.1	17.8	<0.1	0.4	2.2	1.1	0.7	8.9	24.2	<0.1	<0.1	99.6
White glaze	58.4	4.8	0.2	0.5	<0.1	0.4	0.7	2.6	1.0	11.2	19.1	0.1	<0.1	99.0
Yellow glaze	27.0	8.6	0.4	4.7	<0.1	0.7	1.5	0.8	0.7	20.1	35.0	<0.1	<0.1	99.5
Blue glass matrix*	49.9	4.4	0.9	0.5	0.1	0.4	0.85	2.2	1.2	14.8	21.9	<0.1	2.4	99.6
Eastern Chou glass	37.3	0.9	-.-	0.3	-.-	0.6	1.4	5.9	0.2	9.7	37.5	-.-	-.-	93.8
–3rd century *pi* disc	36.8	0.3	0.0	0.1	0.003	0.15	0.5	1.9	0.2	17.4	42.6	-.-	-.-	100.0

* The blue glaze was too weathered for a completely representative analysis.

The bead glazes. The coloured glazes on the bead's surface were applied in a grid pattern with dotted details and were often superimposed. Their colours were a reddish brown, a cold blue, a turbid yellow and a dirty white. Their compositions proved as in Table 73.[62]

Although these bead glazes resemble contemporary Chinese glass, they do not seem to have been made from this material. A great deal of relict material (mainly quartz and albite in the white and blue glazes, and quartz in the red glaze) survives in their structures, and these minerals are not fully fused. This suggests that they are underfired and unfritted glazes, rather than poorly fused glass powders. This was probably a deliberate strategy to prevent the superimposed glazes from merging and running in firing. Also, the relatively high alumina levels in the glazes reflect the use of crushed albite in some glaze batches and the use of clay in others. The alumina levels produced by this approach are uncharacteristic of most Chinese lead-baria *glass* compositions published to date, which can be represented by the analyses in Table 74.[63]

Even so, an apparently unusual group of Chinese glasses does exist that shows some similarity to the glazes on the ash-paste beads. These are three eye-beads from Hui-hsien 輝縣, Honan province. Their analyses were presented by An Jiayao [An Chia-Yao 安家瑤], who dated them to the Middle and Late Warring States period. These glasses not only have high alumina levels, like the bead glazes, but their barium:lead ratios are also similar to the bead glazes (Table 75).[64]

These connections raise the possibility that they may have been made from materials and recipes related to those used for the ash-paste beads, and may even derive from the same locality. Their main differences lie in their soda contents, with the soda levels in the glasses being double those of the glazes, and impossible to supply from albite alone.

LEAD-BARIA GLAZES ON EARLY CERAMIC VESSELS

Besides these relatively abundant Chinese eye-beads, with pale stonepaste bodies, there also exist four small Chinese vessels (9–11 centimetres diameter) that bear similar glazes and decoration to the 'ash-paste' beads.[65] These are not ash-paste wares, however, but are thrown from gritty red clays and are unglazed inside. They tend to be dated towards the 'second half of the Warring States period'[66] and are now in the Nelson Atkins Museum of Art, Kansas City, the Boston Museum of Fine Arts, the British Museum and the Tokyo National Museum. It is thought that all four jars were excavated by Japanese archaeologists in the +1930s,[67] and the British Museum

[62] All figures from Wood *et al.* (1999), p. 31, table 2.
[63] *Ibid.*
[64] An Jiayao (1996), p. 136.
[65] Wood & Freestone (1995), pp. 12–17; Wood (1999), pp. 189–91. Their heights range from 90 to 110 millimetres and their widths from 130 to 150 millimetres.
[66] Hardie (1993), p. 67.
[67] Wang Chhing-Cheng, pers. comm.

Table 74 *Chinese glass beads of the Warring States period*[a]

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	CuO	CaO	MgO	K_2O	Na_2O	BaO	PbO	Total
Green-blue bead	41.4	0.01	0.9	0.3	2.1	1.4	0.2	0.2	5.9	9.7	37.4	99.5
Black bead	37.3	0.05	1.2	7.35	0.4	1.9	0.6	0.4	3.75	9.4	37.5	99.9
Colourless bead	51.3	0.01	0.5	0.1	0.01	0.4	1.5	0.08	6.1	11.4	28.3	99.7
Blue bead	52.4	0.03	1.2	0.3	1.3	1.5	2.6	0.2	10.1	11.1	19.2	99.9

[a] Shi Meiguang *et al.* (1991), pp. 27–30.

Table 75 *Glass eye-beads from Hui-hsien, Honan province, middle and late Warring States*[a]

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	CuO	CaO	MgO	K_2O	Na_2O	BaO	PbO	Total
Glass eye-bead	43.4	-.-	4.8	0.1	-.-	0.7	-.-	0.3	7.3	14.4	26.9	97.9
Glass eye-bead	37.6	-.-	4.95	0.5	-.-	1.75	1.4	-.-	4.5	16.1	32.0	98.8
Glass eye-bead	36.5	-.-	7.4	0.25	-.-	1.7	0.4	-.-	4.7	15.5	31.8	98.3

[a] An Jiayao (1996), p. 136.

vessel is reported as being from Hsün-hsien 濬縣 in Honan province. Three of the jars (two in the US and one in Tokyo) have covers, decorated in the same manner as the vessels.

Nonetheless, and despite similarities, the exact relationships between Chinese glass, Chinese copper-barium paint pigments, the ash-paste beads, and the four polychrome-glazed pottery vessels, remain obscure, as problems with dating make it difficult to establish a proper framework of precedence. An extra element in this puzzle is the existence of a plain glazed vessel in the Nelson Atkins Museum of Art, Kansas City. This is a lidded pottery jar of Warring States bronze-derived *phou* 缶 form, entirely covered by what seems to be a glossy overall lead glaze of a greenish hue. It is not obvious whether this greenish colour is from copper, from iron, or from both. The difficulty with this jar is that it seems to pre-date similar glazes seen on northern Chinese earthenwares by some two centuries.[68] Dots of greenish transparent glaze do occur on some Warring States Chinese glazed beads, however, so parallels to this jar's glaze may well exist in contemporary glazed-bead technology.

This complicated glass-related polychrome glaze technology, used in China for stonepaste beads and for a few rare pottery vessels, was superseded in the Han dynasties by a far simpler approach to earthenware glazing that used plain brown and green lead glazes, coloured with iron and copper respectively. This change seems to provide an unusual example of Chinese ceramic technology becoming less, rather than more, sophisticated with time, and raises questions as to how closely these two traditions were connected. Before true lead glazing became properly established in the later Western Han dynasty (–1st century), northern earthenwares had been enhanced in various ways, including plain lacquer and complex painting with cold colours (see pp. 610–14). However, when the same forms were enhanced with lead glazes, oxidised firings were essential to avoid glaze-damage from reduction, and these oxygen-rich firings gave pale reddish colours to the unglazed areas of the loessic earthenware bodies.

Two examples of green Han dynasty lead glazes (the commonest type) have been analysed quantitatively, with these glazes embodying rather different approaches to glaze design when compared with the polychrome wares that pre-date them (Table 76).

The first glaze can be regarded as a simple lead alumino-silicate, with an oxide-balance close to an eutectic mixture. It is coloured by copper in solution (Cu^{2+} ions), but it also contains some dissolved tin. Tin oxide is present in many copper-green Chinese glazes throughout history and probably represents the use of oxidised bronze as a glaze colourant, as natural copper-tin ores are rare minerals.[69] The remaining oxides that occur in both glazes (of Fe, Ti, Ca, Mg, K and Na) have balances that suggest the presence of loess in the glazes, although whether the loess was

[68] The possibility of deliberate archaism in this jar's design is raised, and then dismissed, by Watson who describes its style as being in 'an idiom distinct from Han imitation of the antique'. See Watson (1984), p. 28.

[69] Wood (1993b), pp. 51–2. Seven green Han dynasty lead glazes studied at the Victoria & Albert Museum in +1992, all proved to contain significant amounts of tin. See Wood *et al.* (1992), pp. 139–40.

Table 76 *Eastern Han dynasty green lead glazes*[a]

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	MgO	CaO	Na_2O	K_2O	BaO	PbO	CuO	SnO_2	Total
From an Eastern Han jar	29.5	3.7	0.2	1.3	0.5	1.9	0.2	0.9	0.2	59.7	1.2	0.2	99.5
From an Eastern Han *ting*	33.4	3.9	0.6	2.0	0.7	2.0	0.4	0.5	7.7	43.5	3.0	1.2	98.9
PbO–SiO_2–Al_2O_3 Eutectic mixture	31.7	7.1								61.2			100.0

[a] Wood *et al.* (1992), pp. 131–4.

digested from the body-surfaces during firing, or whether it was a major component of the original glaze batch, is still not entirely clear.[70] However, the apparent mixing of lead and barium ores with a fusible clay, suggested for the yellow glaze on the faience bead, may stand as some precedent for the latter approach.

The second glaze proved unusually high in barium oxide (7.7%), which does suggest some continuity with early Chinese lead-baria glasses and glazes.[71] In the course of this particular study one further Han lead-baria glaze was identified by qualitative X-ray fluorescence analysis, which gave two lead-baria glazes and six plain lead glazes from the eight examples studied.[72] From this small sample lead-baria glazes appear to be in the minority in the Han, although not particularly rare. However, baria levels of this order do not seem to survive beyond the Han dynasties, and Chinese lead glazes later than this period tend to give baria-free and near-eutectic compositions, not unlike the first analysis in the table.

The true antiquity of lead glazes is of interest to world ceramics in general, particularly as high-lead glazes (where the lead oxide contents frequently exceed 50% of the glaze's weight) became the most successful earthenware glaze-type in history. Glazes of this high-lead style saw extensive use in Egypt, the southern Mediterranean and northern Europe from at least the –1st century to the present day.[73] These glazes show a smooth and even melt during firing, brilliant surface-qualities, and excellent response to colouring oxides, which provide warm saturated colours in both suspension and solution. The low expansivity and good elasticity of lead glazes also helped to prevent crazing, i.e. the net-like cracking of the glaze-coat that develops if it shrinks more than the ceramic beneath in the last stages of cooling. Finally, the insolubility of lead ores in water means that lead glazes do not necessarily need fritting before firing and good lead glazes were

[70] See Hurst & Freestone (1996), pp. 13–18, for an account of this 'digestion of the body-surface' effect.
[71] Wood *et al.* (1992), pp. 134–5.
[72] *Ibid.*, p. 139.
[73] Tite *et al.* (1988), p. 242.

Table 77 *Lead release results from replications of glazes 1 and 2 in Table 76 (in parts per million)*

	Lead	Barium
Glaze 1 no CuO but with 1.0% Fe_2O_3	-.-	-.-
Glaze 1 with 1.0 % Fe_2O_3, 1.5% CuO and 0.2% SnO_2	42	-.-
Glaze 2 no CuO but with 2% Fe_2O_3	1.5	<1.0
Glaze 2 with 2% Fe_2O_3, 3% CuO and 1.0% SnO_2	120	15

frequently made from crushed lead ores mixed with clay, and/or some fairly pure source of silica.[74]

LEAD POISONING

Nonetheless, behind the undoubted advantages of lead glazes lurks a grave potential hazard, namely the high toxicity of lead to the human system. It is possible to be poisoned by lead glazes when preparing them, when firing them (by breathing volatilised lead vapour) and, particularly, when eating or drinking from vessels glazed with them. The fritting of lead glazes has proved the most effective way for protecting potters from poisoning when mixing, applying and firing these glazes, but fritting cannot prevent the release of lead into food or drink from fired glazes.[75]

Lead glazes are not poisonous *per se*, indeed they were the main glazes used on British commercial bone china and white earthenware tableware until at least the +1970s. The chemical stability of lead glazes can be excellent, and their capacity to release lead into food-acids easily controlled by proper formulation. Problems arise when this stability is upset, usually by additions of copper (II) oxide (CuO) to make the glazes green. This destabilising effect of copper was demonstrated by lead-release tests carried out on some reconstructions of the two Han lead glazes described in Table 77.[76]

Lead release from glaze 1 without copper oxide was undetectable, but additions of 1.5% copper oxide and 0.2% tin oxide raised the glaze's lead release to some ten times the British legal limit. Glaze 2 (the baria-containing glaze) was within safe limits without copper and tin, but adding 3.0% copper oxide and 1.0% tin oxide resulted in a lead-release figure some 40 times the legal UK limit. Additions of copper also triggered the release of barium from the glaze, a heavy metal that is almost as toxic as lead.

The destabilising effect of copper on Han dynasty lead glazes had one further effect, namely the tendency for green glazes to weather easily to turbid or iridescent

[74] See Tite *et al.* (1998) for a discussion of the nature and use of historical lead glazes.

[75] Lawrence & West (1982). See chapter 16: 'Lead glazes their use and misuse', pp. 248–59, for an account of the pros and cons of lead glazes.

[76] Wood (1999), p. 195.

surfaces. The silvery and laminated weathering of Han dynasty lead glazes is a familiar sight in museum examples where it can evoke the character of patinated bronze. This is a change that has occurred to shiny green lead glazes over centuries of burial and would have been neither apparent nor exploited when the wares were made.

HIGH-LEAD GLAZES IN WORLD CERAMIC HISTORY

Before lead glazing became established in China, the major earthenware glaze-type in the world was the soda-lime-silicate glaze, with its mid -2^{nd} millennium origins in Iraq. Alkaline glazes of this style were often coloured with copper, which gave turquoise colours, rather than the typical lead-glaze green. Where lead occurred in these Near Eastern glazes the element tended to be associated with yellow lead–antimonate colourants, and usually at levels lower than 5%.[77] A special use of lead in this technology occurred during the development of copper-red glasses in Egypt and the Near East during the -1^{st} millennium but, as mentioned above, even here lead oxide levels rarely exceeded 25%.[78]

Lead glazes in the West, dating from pre-Roman times, have yet to be found. The scholar Alexander Kaczmarczyk reported recently:[79]

> Extensive search by one of the authors (AK), who has examined over 2,000 pre-Roman glazed specimens from several American, European and three Egyptian museums (Cairo, Alexandria and Coptic), failed to turn up a single example of a clay object bearing a lead glaze.

High-lead glazes, however, were used within the Roman Empire, where transparent copper-green glazes were also popular colours. Roman lead-glaze technology seems to have started in western and southern Asia Minor during the early Imperial period (-2^{nd} century to $+1^{st}$ century), and lead-glazed wares from these areas were imported to Italy.[80] Walton and Tite summarise the early spread of Western lead glazes as follows:[81]

> Lead-glazed pottery appeared suddenly in Hellenistic Asia Minor in the 1^{st} century BC. Although this type of pottery was produced on only a minor scale, it was finely made with appliqué decoration that was close in its form to repoussé silver . . . Lead glazes spread throughout the Roman Empire via troop movements with the eventual establishment of workshops in central Gaul, in Moesia Superior (present-day Yugoslavia) and possibly in Italy.

[77] Claims for high-lead compositions for Near Eastern glazes, such as those used on glazed bricks from Susa in Persia (-6^{th} century), seem to have been based on the normalisation of analyses of antimony-yellow and antimony-copper-green glazes, from which most of the alkalis had been leached by weathering. See Fukai Shinji (1981), p. 11. This has resulted in the reporting of lead-levels at many times their original presence.

[78] Freestone (1987), p. 186, writes: 'Second millennium [BC] opaque reds were essentially free of lead. Sometime in the first millennium the benefits of lead were discovered and two types of [copper-red] glass were produced: high-lead high-copper and low-lead low-copper types. Given the good separation of these groups it is probable that they represent two intentionally produced types rather than a single continuum.'

[79] Kaczmarczyk in Hatcher *et al.* (1994), p. 431.

[80] Roberts (1997), p. 190.

[81] Walton & Tite (forthcoming; from the abstract of a paper presented at the 33^{rd} International Archaeometry Symposium, held in Amsterdam in 2002).

Pérez-Arentegui *et al.* have also examined Roman lead-glazed wares, in this case of the +1st to +3rd centuries, and found in Spain. They believe that these wares were imported to North Eastern *Hispania*, largely from Augustean Gaul, and from another source that 'has probably an Italic origin'.[82] The former group bore lead glazes applied to reddish non-calcareous bodies while the second group, possibly from Italy, are predominantly calcareous with CaO contents usually in the 10–21% range. They often bear distinctive green and yellow glazes applied to the same vessels.

Nonetheless lead-glazed wares remained rare amongst Roman ceramics which, like the Greek wares before them, were usually finished with glossy and vitreous illitic slips. In these clay-rich compositions the main glaze-flux was potassium oxide, and most of the gloss was supplied by refined platy materials drying flat on the surfaces of the wares, rather than by true glass.[83] Most examples of Roman lead-glazed wares are dated to between the middle of the −1st century and the +1st century. Hatcher *et al.* write that:[84]

> There is at the present time no evidence that lead glazing of clay, which gives a satisfactory coating and adheres well, was practiced prior to the first century BC.

However, one should note that this judgement is more applicable to the West than to China.

The analyses from the Spanish authors and from the Oxford team are comparable and show that Roman glazes are generally higher in both lead oxide (68–86% PbO) and calcia (1–10% CaO) than their Chinese equivalents, with typical calcium oxide contents in the Roman examples of about 3–4 % CaO (Table 78).

These elevated calcium oxide contents seem either the result of using body-clays in the glaze recipes or from the bodies' diffusing into the glazes somewhat during firing. With the Italian lead glazes, their compositions may reflect the practice of combining ground siliceous sands with the raw lead ores in order to make the glaze mixtures.[85] In fact a lead ore + sand approach seems more typical of Roman lead-glaze technology than the lead-ore + siliceous clay mixtures, suggested for Han dynasty Chinese lead glazes.

The presence of small amounts of calcia must have improved the stability of Roman lead glazes, and discouraged lead release into food to some extent, although the use of copper oxide to produce a green colour in 49 out of 93 Roman glazes tested by Helen Hatcher and her colleagues would have negated this effect and rendered the green-fired glazes quite toxic.

As to questions of precedence, Roman and Chinese lead glazes came to life at about the same time (−1st century), but there are some rare examples of Chinese-made

[82] Pérez-Arantegui *et al.* (1995), p. 216.
[83] Tite *et al.* (1982). Hatcher *et al.* (1994), p. 432, note that out of fifteen tons of Roman pottery excavated at Colchester, England, since 1971, 'only 700 grams were accounted for by glazed vessels'.
[84] Hatcher *et al.* (1994), p. 444.
[85] Hatcher *et al.* (1994), p. 444.

Table 78 *Analyses of bicolour Roman lead glazes, +2nd to +3rd centuries*[a]

Glazes	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	K_2O	BaO	PbO	CuO	SnO_2	Total
V-59 green	18.4	2.3	-.-	1.7	4.1	-.-	0.5	-.-	0.5	-.-	70.4	2.5	-.-	100.4
V-59 yellow	19.9	2.1	-.-	3.8	4.2	-.-	0.4	-.-	0.4	-.-	69.7	0.0	-.-	100.5
V-69 green	17.0	2.3	-.-	1.8	3.3	-.-	-.-	-.-	-.-	-.-	73.6	1.9	-.-	99.9
V-69 yellow	18.0	1.8	-.-	4.5	2.5	-.-	-.-	-.-	-.-	-.-	73.3	0.0	-.-	100.1
V-83 green	20.4	2.1	-.-	2.4	3.4	-.-	0.65	-.-	0.65	-.-	68.3	2.8	-.-	100.7
V-83 yellow	21.3	2.5	-.-	4.9	4.7	-.-	0.8	-.-	0.8	-.-	65.8	0.0	-.-	100.8

[a] Walton & Tite (forthcoming). Pérez-Arantegui *et al.* (1995), p. 214, table 2.

bead glazes that show use of the high-lead principle as early as the -4^{th} century.[86] The technique may have been applied to a few rare pottery vessels in China not long after this date. The Warring States lidded jar of bronze *phou* form in the Nelson Atkins Museum of Art, mentioned on pp. 480–2, may represent the earliest surviving example of this new approach to glazing in ceramic history.[87] These facts, and improved chronologies for the beginnings of lead glazes in the West, rather change the conventional views of the subject that had tended to see Parthian influence on the origins of lead glazing in China in the -2^{nd} century.[88] However, slightly later technological transfers in either direction between the Han and Roman empires still cannot be entirely discounted.

From the studies cited above it is beginning to appear that the first use of high-lead compositions in *glazes* may have taken place in China early in the Warring States period, rather than in the Roman Empire. The use of such glazes in China probably began on ceramic beads rather than on vessels. The essential principle of a lead-fluxed silicate, however, was Mesopotamian, and seems first to have been developed for the manufacture of cuprite-red glass. It is perhaps from this source that Roman lead glazes evolved, but other theories proposed include the cupellation of silver from lead-silver ores, and from experiments made with lead-antimonate glass.[89]

[86] Wood *et al.* (1999), p. 31, table 2.
[87] Reported and illustrated in Wood & Freestone (1995).
[88] Parthian influence on the beginnings of Chinese lead glazing was championed by Leach (1940), p. 136, and Wulff (1966), pp. 140–1.
[89] The glass aspect of this subject is well explored in Mass *et al.* (1997), pp. 193–204.

LEAD GLAZES FROM THE THANG DYNASTY ONWARDS: VESSELS, TILES AND ASSOCIATED WARES

A fallow period in the +4th, +5th and +6th centuries for vessel manufacture was nevertheless an important time for new developments in the use of lead glazes in the north for tiles and architectural ceramics. As far as vessels were concerned, it was not until the Thang dynasty that a spectacular revival occurred when splashed, streaked, trailed, resisted, dripped and mottled coloured lead glazes were applied to funerary ceramics.

THE USE OF TILES IN CHINESE BUILDINGS

An earlier volume in the series has dealt at length, and in some detail, with the subject of building technology.[90] It included information on theory, planning and construction, together with a review of the Chinese literature on building science. Individual components of architecture were considered, such as foundations, pillars and roofs. From the general principles observed in that book, discussion will be narrowed down here to focus on individual architectural elements that employed ceramics. Building materials in early China are described in an earlier section of the present volume (pp. 104–15). The materials there reviewed were produced, in the main, from unglazed loessic earthenware and stoneware. The story continues with glazed architectural ceramics.

Glazed tiles used in architecture have two aspects, function and ornament. High-fired tiles with vitrified glazes that fully bonded to the body were very rare in early times, and their use was not widespread before the +20th century. Most glazed tiles in China had low- to medium-fired earthenware or stoneware bodies, and glazes that tended to flake off when subjected to long-term weathering. Thus they could not be said to be a truly durable building material. Nevertheless, they were more resistant to decay than wood or thatch, and cheaper than metal.

In practical terms, ceramic tiles helped prevent the spread of fires. The replacement of traditional thatched roofs with tiled roofs was strongly encouraged in early times. For example, in the Thang period it was official policy in Ling-nan 嶺南 (Canton) to instruct the populace in the use of roof tiles, to prevent tragedies caused by fires,[91] while in the Sung dynasty an executive order was sent to Yang-chou 揚州 to use tiles, so as to prevent conflagrations that were common among old thatched dwellings.[92]

[90] Cf. Needham *et al.* (1971), pp. 58–144. Some of the material reviewed here was included in Kerr (1999).
[91] *Hsin Thang Shu*, ch. 163, p. 5032.
[92] *Sung Shih*, ch. 465, pp. 13594–95.



Fig. 133 Funerary model of a horse, Thang dynasty, early +8th century, with mottled and plain lead glazes and circular resist pattern

In decorative terms, glazed tilework had many advantages. From a distance, it could be as bright and as reflective of light as precious metal. The late +13th-century traveller Marco Polo was inspired by the site of the Mongol capital Ta-tu 大都 (present-day Peking) to write:[93]

The roof is all ablaze with scarlet and green and blue and yellow and all the colours that are so brilliantly varnished that it glitters like crystal and the sparkle of it can be seen from far away.

[93] Latham (1958), p. 126. Quoted in Krahl (1991), p. 47.

Tilework permitted the use of a wide range of colours, either in blocks of a single tone for emphasis, or in several shades together for contrast. It was even possible to paint designs on the surface of tiles, thus adding an extra layer of complexity and richness to this form of architectural adornment.

Glazed tiles have been used in many parts of the world. While sweeping generalisations should be treated with care, it is broadly true that glazed tilework was more widely employed in hot climates than in temperate ones. This indicates another property enjoyed by tiles, that of promoting coolness when used on the interior of buildings. For example, artisans working within the Islamic cultures of West Asia were among the most notable proponents of glazed tilework in architecture. They employed tiles on the exterior of structures for splendour, and on the interior for comfort. Furthermore, they were able to decorate the tiles with moulded and glaze-painted designs that charmed the eye in secular building, and offered appropriate homage to God on religious structures. Tiles constituted an ancient Mesopotamian form of wall decoration that flourished in Assyrian times, and was revived by Islamic tile-makers in the +9th century. Monuments of this period, such as the Great Mosque at Kairouan (+836, +862 and +875), bore dazzling arrays of tilework. Some of the earliest Islamic buildings, however, such as the Dome of the Rock in Jerusalem (completed +691), were originally embellished with mosaic and marble. This was only replaced in Ottoman times by magnificent Turkish tiles.[94]

Over the last 150 years, glazed tiles have become more commonplace as a feature of occidental architecture. But nowhere were they employed so consistently as in China, where their use can be traced back at least 1,500 years and where they continue to be applied to architecture today. Though tiles were also used to clad interior and exterior walls, for architectural ornament and for vessels, their main association is with roofs, a component of buildings that we can be explored through consideration of the function of roofs in Eastern and Western terms.

Roofs in West and East

In Western architecture, roof structures changed and evolved, with some features of their designs linked to symbolic functions. A difference was often marked between religious and secular structures. Religious buildings, whether temples, mosques or churches, had roofs that suggested underlying spiritual messages; domes that arched like the heavens, minarets and spires that stretched towards celestial realms. Sometimes, roof forms common in religious structures were appropriated to glorify the residences of earthly rulers.[95] In secular building, roofs were usually envisaged in straightforward terms, as means of finishing structures and making them weatherproof. The writings of the great Italian architect Andrea Palladio (+1508–80)

[94] Cf. Ettinghausen & Grabar (1987), pp. 30, 98, 116; Insoll (1999), pp. 49–51.

[95] A paradigmatic building of this type was Nero's Golden House in Rome (+64–8) with its dominating domed roof. Cf. Boëthius & Ward-Perkins (1970), pp. 248–50, fig. 98, pl. 130.

exemplified this direct approach. In +1735 an English translation of his work was published, from the original text produced in Venice in +1570:[96]

> Concerning Roofs: When we have carried the Walls as high as we are determin'd they shall go, when we have made the Vaults, laid the Joists of the Floors, brought up the Stair-Cases, and in short, done every Thing which we have already taken notice of, in the next Place we must raise the Roof, which, as it embraces all the Parts of the Fabrick, and Presses the Walls thereof equally with its Weight, is by that Means a kind of Bandage to the whole, and serves not only to shelter such as live in the House from Rain, Snow, the Sun's burning Rays, and the vapours which arise in the Night, but is also of great Service to the whole Edifice, as it carries off the Rain from the Walls . . .

The comforting notion of the roof as a bandage to keep out inclement weather is matched by a vision of it being the top or lid of a building; 'topping out' is a term still used by the construction industry when celebrating the successful completion of roofing.

In East Asia also, roofs embodied both practical and spiritual forces. Chinese architecture has relied on a simple timber-frame, post-and-beam construction since the late Neolithic period.[97] Upright timber columns supported cross-beams that were placed one on top of the other, in diminishing order of size, to create a pitched roof in a number of steps. Projecting eaves, supported on eaves purlins resting on the cross-beams, protected against rain. The whole roof structure was tiled. This form of building depended on modular beam construction for its support. Walls added in later were not load-bearing, and were often plain and unadorned.[98] Architectural ornamentation was confined to the roof and, to a lesser extent, to doors and windows. Interior columns, beams and plastered walls of grander palace and temple buildings bore mainly pictorial designs.

Status and function were conveyed by the size of buildings, by choice of site and by defining ornamentation, such as the choice of roof tile. Building size was based on the extension of a number of *chien* 間 or bays, a spatial formula defined by the upright columns. Most large buildings extended laterally, around a courtyard system. The scale of Chinese buildings, whether religious, royal or vernacular, was based on these simple formulae.[99] With a few exceptions, such as the distinctive pagoda,[100] all structures followed a similar, basic prototype.

[96] Hoppus (1735), p. 69. Palladio's influence on European architectural philosophy, particularly in England, has been enormous. Fashionable in the eighteenth century, his 'Five Orders' are still invoked by one wing of the architectural establishment today.

[97] See Knapp (2000), pp. 72–3, 88–9, for description of wood-framed buildings at Ho-mu-tu 河姆渡.

[98] Needham *et al.* (1971), pp. 90–104.

[99] Cf. Paludan (1981), pp. 38–40.

[100] *Stupas* were transported from India along with Buddhism in the +1st century, and Needham discusses their fusion with Han tower architecture, Needham & Wang (1965), pp. 61, 69, 128–9, 137–41. Like their Indian counterparts, Chinese pagodas were designed and built to accommodate Buddha's relics. Many early pagodas were built of wood and so do not survive. The first pagoda to be built in China was that at the centre of the White Horse Temple (*Pai-ma Ssu* 白馬寺) monastery in Lo-yang, no longer extant, that was constructed in +68. See Lo Che-Wen (1990), pp. 11, 19, who quotes an early reference in the 'Annals on Buddhism and Taoism' (*Shih Lao Chih*) in the *San Kuo Chih (Wei Shu)*.

In symbolic terms, however, different parts of buildings in East Asia were endowed with strong spiritual values. The roof, by virtue of its position on top of and at the highest point on a building, was deemed a point of communication between heaven and earth. Thus it acted as a bridge to the world of spirits and a platform for spirits to descend to and ascend from earth.[101] This capacity was important to the functioning of religious and ceremonial buildings, but can also be observed in the depiction of domestic structures. For example, some tomb murals of the Han dynasty portrayed the occupant as he was in life, showing him with his family enjoying earthly pleasures. Hunting, feasting or listening to music, he was surrounded by trappings of wealth and achievement. On the roof of his palatial home danced phoenixes, dragons or two-headed birds. These miraculous beasts perhaps denoted non-worldly, spiritual aspects of human experience.[102]

An underlying reason to ornament buildings was to aid communion with the celestial world and to attract good protection and blessings. The decoration of roofs expressed spiritual needs; decoration was abundant on this section of the building both for that reason, and also because of the nature of Chinese construction methods. Both of these particulars provide further points of contrast with building traditions further west. For example, the Hindu and Buddhist architectures of India and parts of South-east Asia, in which stone and brick were also important building materials, provided strong walls as ample ground for decoration. Indeed, early Buddhist sanctuaries of the -1^{st} century in India were frequently carved into rock faces, a concept carried to China and expressed in the great cave temple sites there.[103] In India though, unlike the major trend in China, the sculptural quality of buildings continued when structures became free-standing. Walls were adorned with friezes and niches containing sacred figures.[104] On some monuments in South-east Asia, this tradition was enriched to the point where sculptural decoration extended over the entire surface of walls.[105]

[101] Idea formulated in Legeza (1982), p. 106.

[102] Michele Pirazzoli t'Serstevens (pers. comm.) confirmed that this tradition of representation is commonly found in northern Chiangsu and southern Shantung provinces, but not in Honan, Shensi or Szechuan provinces, during the Han period. There is disagreement among experts as to the exact meanings of the depiction of fabulous beasts on roofs. To date no regional studies of Han iconography have been published. James (1996), pp. 13, 61, 94, identifies the long-tailed phoenix (*feng-huang* 鳳凰) as a signifier of good auspices to tomb occupants, reflecting their high moral character.

[103] Among the most noted are the Tun-huang 燉煌 caves dug into the yellow earth of Kansu province (+366 to *c.* +1000); the Yün-kang 云崗 caves in Shansi province, hollowed out from the sandstone cliff formed by the Wu-chou river 武州河 (+453 to *c.* +525); the Lung-men 龍門 caves in Honan province, carved into the limestone cliff face of the I river 伊水 (starting *c.* +500). Cave temples at Mai-chi-shan 麥積山 in Kansu province and Ta-tsu 大足 in Szechuan province are also notable.

[104] Many monuments could be singled out as instances of wall-borne architectural decoration. Rowland (1967) describes the Gupta period (+320 to +600) chaitya-hall as being the first free-standing temple of permanent materials, its elaborately decorated façade completely filled with niches containing religious statuary. Other individual examples are the Mahabodhi temple at Bodh Gaya (façade carved $+8^{th}$ to $+12^{th}$ centuries) and Brahmanical building in Kashmir of the $+8^{th}$ to $+13^{th}$ centuries. Rowland (1967), pp. 68, 98, 119, 130–3.

[105] Rowland (1967), pp. 215–54, discusses the architecture of Sri Lanka, Cambodia and Thailand. An exemplar (*ibid.*, p. 239) is Angkor Wat at the city of Angkor in Cambodia, built +1113–5, in which sumptuous sculpture extends over the entire surface like a continuous stone tapestry. See also Rooney (1994), pp. 84–108.

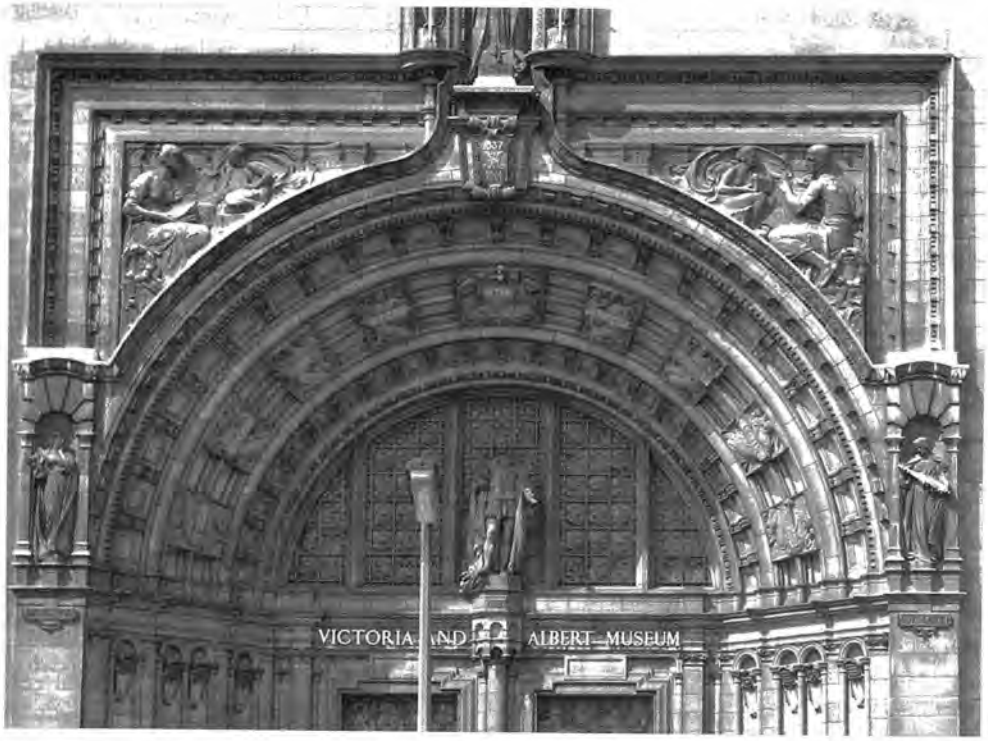


Fig. 134 Detail of sculptural façade of the Victoria and Albert Museum, +1900–08

In Europe, where important structures were also often supported on solid walls, more sculptural decoration was concentrated on walls, doors and windows, than on roofs. Moreover, embellishment on religious and secular monuments was often concerned with temporal virtues. A splendid +20th-century example is provided by the façade of the Victoria and Albert Museum in London, whose sculptural decoration includes Queen Victoria and Prince Albert, and symbolic imagery celebrating Truth, Beauty, Inspiration, Knowledge and the Arts.

Decoration of Chinese Roofs

Chinese builders sought to harness propitious spiritual forces and to repel evil influences by means of applied ornamentation that carried symbolic meanings. On roofs, the most common medium for decoration was tiling. The transposition of cosmic ideas derived from philosophical Taoism with elements of folklore was common. This is illustrated by the major motif of the roof ridge, a rising wing-like tile construction placed at either end of the ridge and known in Chinese as *chhih-wei* 鴟尾 (literally 'owl's tail'). Such ornamentations have been found at imperial tomb



Fig. 135 The Hall of Supreme Harmony with dragon tiles on the roof, seen from the Meridian Gate, +1997

and palace sites dating from as early as the +6th century.[106] By the Sung dynasty (+12th to +13th centuries) its form had developed to become a dragon with a serpentine tail. On later buildings the tail was often shown as that of a leaping fish, and this association links fish with dragon, and both with water and the control of water for flood, drought and fire.[107]

That protective function was reinforced by the dragon, a creature linked with water and credited with the power to gather clouds and make rain, thus preventing conflagrations.[108] Dragons were common features on flammable Chinese wooden buildings, both on roof tiles and as decorations on other items. Dragons were especially numerous on imperial structures, by virtue of their association with the imperial family. Their efficacy in preventing fire was questionable; many are the stories of buildings lavishly adorned with dragons that burnt down soon after construction. An example was the Hall of Supreme Harmony 太和殿, one of the three great halls at the front of the Forbidden City in Peking. It bore gaping dragon tiles on its roof

[106] Ridge decorations of this type are seen in the Six Dynasties period and have become mature by the Thang dynasty, cf. Chhi Ying-Thao (1978), pp. 67–8, figs. 3–4. Thang dynasty tiles from the site of the Upper Capital of the Po-hai 渤海 kingdom at Ning-an 寧安, Heilungchiang 黑龍江 province, can be seen in the Museum of Chinese History, Peking, cf. Krahl (1991), p. 50.

[107] The fish-transforming-into-dragon is illustrated literally in the myth of 'Carp Leap over Dragon Gate', see Birrell (1993), p. 242.

[108] Dragon mythology is discussed by Werner (1961), pp. 285–97.

ridge that were eleven feet in height, made up of thirteen sections and weighing 4.3 tons each. Yet less than a year after its construction in +1420 the hall was consumed by flames. It was rebuilt, but burned down three more times.[109]

One measure of a building's importance was the nature of its glazed roof-tile decoration. Many three-dimensional figures could be added, each made in one piece with the tile on which it sat. Size and number of creatures depicted were both significant. Thus the Meridian Gate 午門, the southern entrance to the Forbidden City, had nine figures on its eaves plus an immortal rider at the front, while the Hall of Supreme Harmony had a total of eleven figures. The length of the series varied according to the importance of the building, but it was always supposed to be an uneven number and never to exceed eleven figures. Uneven numbers provided further links to cosmological theory for they belonged to the *yang*, or male, dominant element and thus represented strength and good fortune.[110] A fixed rank for the figures was introduced during the Ming dynasty. Before that, as far as is known, a greater variety of creatures were placed on buildings in a more haphazard way.[111]

There was regional variation in the type and sequence of creatures used on roofs. In north China, it was common to place a row of animals descending the ridge, chosen in order from the following series: celestial horse, *chhi-lin* 麒麟 (a magic unicorn-like creature), lion, phoenix and dragon. At the bottom, perched on the very edge of the roof, was a seated rider. Originally representing one of the Four Directional Spirits, folk mythology altered the iconography to represent wicked Prince Min of the state of Chhi 齊湣王. The story that this cruel tyrant was captured in –383, strung from the corner of a roof and left to die, explains the link.[112] He was sometimes shown in tile form riding a hen, a protective combination because his weight was believed to be too great to allow the hen to fly to the ground. On the other hand, he could not climb back up the roof because its ridge was guarded by the topmost gaping dragon ridge tile.

The halls of important buildings in north China sometimes bore other creatures of the zodiac, though a whole set was rarely if ever employed. Zodiac animals such as ox, tiger, hare, horse, ram and dog appeared alongside creatures such as lion and elephant, and mythical animals like *chhi-lin* and *suan-ni* 狻猊. These combinations of beasts were not only seen on roofs, but also on structures like gateways and dragon walls.[113] Other popular devices for tiles included the representation of frightening

[109] Weng Wan-Go & Yang Boda (1982), p. 41.

[110] Needham & Wang (1959), p. 55, mention the widespread Chinese superstition that odd numbers were lucky and even ones unlucky.

[111] Paludan (1981), p. 62.

[112] *Ibid.*, p. 62. Details of the life of this feared but militarily successful prince can be found in *Chung-Kuo Jen-Ming Ta Tzhu-Tien*, p. 1427.

[113] The free-standing dragon wall seems to have originated in Shansi province. Most famous is the nine-dragon wall at Ta-thung 大同 (+1392). However, there are two further nine-dragon walls of the Cheng-Te and Thien-Chhi reign periods, three five-dragon walls, three three-dragon walls, four two-dragon walls and one single-dragon walls in Shansi, cf. Chhai Tse-Chün (1991), p. 17. All these structures precede the noted Chhing dynasty nine-dragon walls in Peking, one of which is in the Forbidden City and one in Pei-hai park 北海公園 nearby.



Fig. 136 Roof ridge of a temple at Chheng-te 承德, showing row of figures with seated rider, +1982

demon figures, credited with powers similar to the terrifying ceramic guardian figures placed in tombs, or carved in stone or wood at the entrance to temple halls. Some of the demons had specific functions, like the thunder god and his partner the goddess of lightning. Thunderstorms represented real threats to wood-built Chinese structures. Celestial officials and warriors, either seated or on horseback, were common devices. The *Lu Pan Ching* (Classic of Lu Pan, +15th century) mentions a character called the Roof-Tile General (*Wa chiang-chün* 瓦將軍), and illustrates a seated figure in armour. Explaining the powers attributed to this figure, and the ritual required for his placing, the text gives us some indication of the influence exerted by different tile figures:[114]

If a Roof-Tile General is placed, it is because there is a monster's head, a ridge of a house, the top of a wall, or a ridge of an honorific arch facing the house. If there is another house in between, a Roof-Tile General should be used . . . One chooses a day of the month when the spirit [of the Roof-Tile General] is present. If on the selected day the weather is clear, placing will be favourable; if it is raining, the day should not be used. If the general is nevertheless placed, the effect will be harmful . . . Before the General is put on his place, an offering of the three sacred animals, wine, fruits, paper money, incense and candles should be made first.

[114] Appendix 'Secret Charms and Magical Devices', p. 2a. Quotation translated by Ruitenbeek (1993), pp. 291–2.

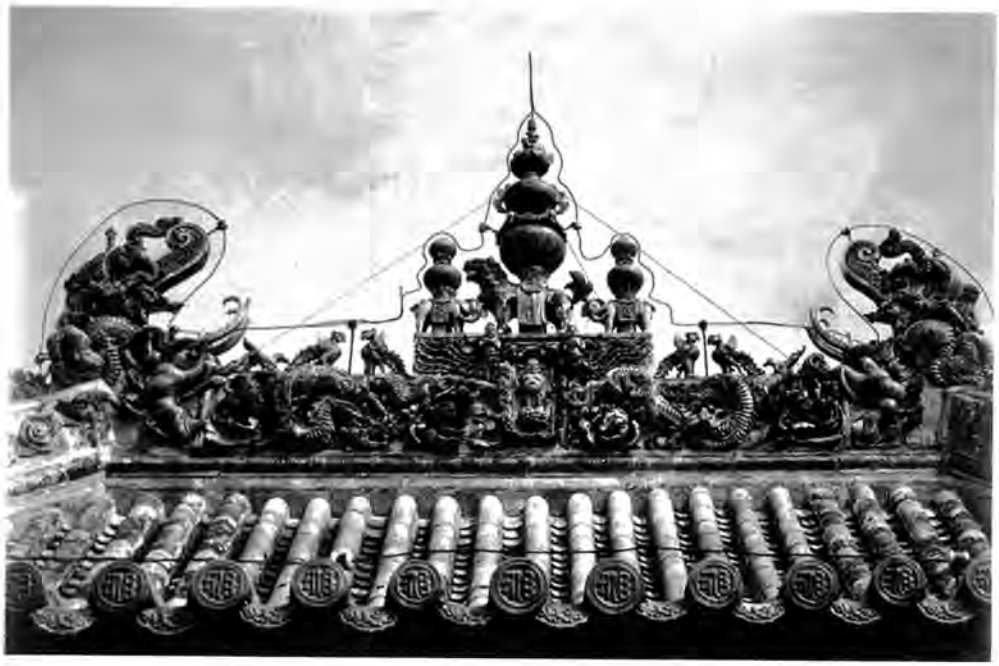


Fig. 137 Roof ridge of the upper Kuang-sheng temple at Hung-thung in Shansi province, +1452

The roof ridge of halls in northern China bore further figures. These often correlated to the Buddhist or Taoist denomination of the temple. The roof ridge of the upper Kuang-sheng temple 廣勝寺 at Hung-thung 洪洞 in Shansi province (+1452), for example, displays a central standing Buddha figure, above him flying *apsaras* plus a lion and two white elephants bearing sacred jewels, and flanking him dragons, phoenixes and a pair of *chhih-wei.*

In south China, roof decoration reached its zenith during the late Chhing period. Then, roof ridges were more likely to be decorated with the three Star Gods of Long Life, Happiness and Prosperity. The lower roof area might bear paradise scenes in place of zodiac creatures; paradise settings were especially common in the southern provinces of Fukien and Kuangtung. The auspicious fish, the golden carp, was also popular there. The upper roof ridge of the Ancestor temple 祖廟 at Fo-shan 佛山 in Kuangtung province, for example, displays a huge pair of leaping fish, while both upper and lower roof-surrounds bear tableaux of immortals, fabulous beasts and scenes from classical literature.[115]

TILE MANUFACTURE

Tiles with coloured glazes were first produced for the palaces built for the emperors of the Northern Wei dynasty at their capital Phing-chheng 平城 (present-day Ta-thung),

[115] Cf. Anon. (1982a), pp. 211–13 pls. 30–3. The temple dates to the Kuang-Hsü reign period.

from the late +4th century. As Chhai Tse-Chün notes, their manufacture and visual impact were commented on in *Wei Shu* (History of the Northern Wei Dynasty, +544) and also in *Thai-Phing Yü Lan* (A General Record of Writing of the Thai-Phing Reign Period, +978).[116] Archaeological excavation of tile sherds with green lead glaze at the city site confirmed the historical record.[117] From another Northern Wei site at Lo-yang 洛陽 we know that tile production was highly regulated. Tiles from the latter site were inscribed with information regarding date (month and year) and a hierarchical division of labour, comprising the names of the two site foremen (*thui-chu* 頹主), skilled potters (*chiang* 匠), potters who made cylinders for tiles (*lun* 輪), potters who cut and pared the tubes into tiles (*hsiao-jen* 削人), and lastly potters who finished the surface of tiles (*khun-jen* 昆人).[118] Coal was already being used to fire the kilns in which such tiles were fired (cf. note 71 on p. 316 and p. 423). The excavation of an Eastern Han tile kiln at Lo-yang revealed an edifice nearly seven metres in length, semi-subterranean and with thick buttressing walls. It was a square-section, cross-draught kiln with a chimney at the back, and although the form of its roof was lost, it resembled a classic northern Chinese *man-thou* kiln 饅頭窯 in design.[119] Another cross-draft tile kiln at Lo-yang, active between +605 and +731, showed only small differences in design. In section it was broader at the back than the front, a form called in Chinese 'horseshoe-shaped'. Slightly larger in size than the Han dynasty kiln, it also was dug deep into the insulating loess.[120]

Excavated remnants of decorated, green-glazed tiles from Sui dynasty sites showed continued tile production during that period.[121] Textual evidence identified a talented potter by name, one Ho Chhou 何稠. A native of Chiang-ling 江陵 in Hunan province during the Sui dynasty, Ho was praised in the Standard Histories of both the Sui and Northern Dynasties.[122] The son of jade carver Ho Thung 何通, in his teens he went to live in Chhang-an 長安, the capital after the fall of Chiang-ling. He travelled widely and was skilled in textile design and glass, in addition to excelling in the production of green-glazed tiles. Such multifarious talents were not unusual, as biographies of other artisans show (see pp. 31–3).

Vessels and Tiles in the Thang Dynasty

Coloured lead glazes were applied freely to large press-moulded horses, camels and mythical beasts, as well as to jars, dishes, vases, cups and ewers. Many patterns were taken from tie-dyed and dye-resisted Central Asian textiles (see Fig. 133), but inlaid

[116] Chhai Tse-Chün (1991), p. 4.
[117] Chiang Hsüan-I (1959), pp. 8–10.
[118] The site was that of the Northern Wei ancestral temple at Lo-yang, and it yielded 865 tile sherds, including 43 sherds that were inscribed with the names of more than 230 separate individuals. The tiles at this site were not glazed. See Anon. (1973), pp. 209–17, pl. 1. The sequence of tile-making operations suggested by the Lo-yang inscribed tiles is confirmed by later Sung and Ming dynasty texts; *Ying Tsao Fa Shih*, ch. 15, pp. 105–11, and *Thien Kung Khai Wu*, ch. 7, pp. 1a–2a.
[119] Anon. (1997a), pp. 47–51.
[120] Anon. (1999c), pp. 16–19, 22, pl. 3.
[121] Chhai Tse-Chün (1991), p. 4.
[122] *Sui Shu*, ch. 68 ('*Lieh Chüan*'), p. 33. *Pei Shih*, ch. 90 ('*Lieh Chüan*'), p. 78. See also Anon. (1959a), pp. 19–20.

designs on Chinese metalwork, and sprigged designs reminiscent of Thang dynasty architectural mouldings, were also borrowed by potters to enhance their wares.[123]

It is apparent that the Thang dynasty was a time when production of lead- and alkali-glazed earthenwares and stonewares flourished. Items were mainly made for burial, though a limited range of *san-tshai* 三彩 was also exported (see p. 716 and pp. 730–3). One would expect that the allied ceramic tradition of lead-glazed architectural ceramics would prosper at the same period, especially in north China. This was the case; excavation has revealed many tile centres, among them Chieh-hsiu 介休 in Shansi province, Chhang-an in Honan province and the Po-hai kingdom 渤海國 of north-east China.[124] Meticulous records of the excavations at Huang-pao 黃堡 in Shensi province provided a small number of tile fragments, including a magnificent *san-tshai* dragon's head tile 24 centimetres long, with a fine white body.[125] Liao dynasty kilns continued the traditions of *san-tshai* in the north; one site making both white porcelain and lead-glazed wares was excavated in Men-thou-kou 門頭溝 district outside Peking in +1983.[126]

Major kilns producing lead-glazed wares during the Thang dynasty have been identified at Huang-pao in Shensi province (supplying the city of Chhang-an)[127] and Kung-hsien 鞏縣 in Honan province (supplying Lo-yang),[128] as well as in Nei-chhiu county 內丘縣 in Hopei province.[129]

The excavations at Huang-pao have provided a good image for the industry, as some loess-cave workshops used for the production of lead-glazed earthenware were hastily abandoned in the mid +8th century due to flooding of the Chhi-shui 漆水 river, leaving pots at all stages of manufacture. Dwellings and workshops at this site were found together, dug back from the river-bank into a loess cliff, with one particular cave-dwelling serving as both living quarters and warehouse. Besides finished glazed wares the excavated workshops yielded hundreds of unfired wares, together with ceramics moulds and biscuit-fired objects. Coins from the reign of the emperor Hsüan-Tsung (+713–741) were found in one workshop and the kiln remains were of the wood-burning *man-thou* style. Coal seems to have been employed to heat the workshops.[130]

THANG DYNASTY LEAD-GLAZED WARES

Three of the colours used for lead-glazed wares – copper-green, iron-brown, and transparent glaze – had already seen use in burial wares in the Eastern Han period,

[123] See Watson (1984), pp. 50–7, for an account of the forms and ornament of Thang dynasty burial earthenwares.
[124] Chhai Tse-Chün (1991), p. 5.
[125] Anon. (1992a), vol. 1, pp. 67–9, vol. 2, col. pl. 2.
[126] Zhao Guanglin (1985), p. 91.
[127] Anon. (1992a), vol. 1, pp. 15–25.
[128] Li Zhiyan & Zhang Fukang (1986), pp. 69–76; Li Jiazhi *et al.* (1986b), pp. 129–33; Rawson *et al.* (1989), pp. 39–61.
[129] An exhibition of excavated ceramics from kilns in Hopei province at the Hopei Provincial Museum, visited by one of the authors (RK) in +1998, displayed a range of *san-tshai* wares from kilns at Nei-chhiu.
[130] Tu Pao-Jen & Cho Chen-Hsi (1987).

but Thang dynasty potters added a cobalt-blue glaze and two types of black to the existing palette. The matt and microcrystalline black glazes were made by overloading the lead-rich base-glazes with copper (II) oxide and with iron (III) oxide respectively. Earthenware glazes on burial wares can also occasionally include small areas of a copper-derived turquoise-blue glaze, which brings the number of possible earthenware glaze-colours to six.[131] The popular name for lead-glazed earthenwares during the Thang dynasty, *san-tshai* (meaning 'three-coloured' ware, see p. 148), therefore underestimates the full range of colours applied to these wares, although it does describe the most typical Thang dynasty lead glazes, namely straw, amber and green.

Thang dynasty lead glazes were applied to underfired stonewares and porcelains, rather than to the reddish loessic bodies typical of Han dynasty lead-glazed ceramics. These white, buff or pink grounds improved the colours from the more transparent coloured glazes and were often covered with whiter slips made from related materials for maximum effect. The use of light-firing kaolinitic clays as grounds for lead glazes seems to have been an innovation of the Northern Chhi period, and early examples of the technique can be traced to kilns in northern Honan province.[132]

Excavation of *san-tshai* kiln sites shows that lead glazes were usually applied to biscuit-fired wares, with the great majority made for placement in tombs. Typical biscuit-firing temperatures for tomb ceramics were about 850–1,000°C, but some late Thang dynasty *san-tshai* wares exported to Mesopotamia show signs of much harder initial firings (*c.* 1,200°C) in order to toughen them for their long trade journeys and eventual domestic use.[133] This concept of 'hard biscuit and soft glaze' was pioneered in *san-tshai* wares in the +9th to +10th centuries, and was later adapted for *fa-hua* 琺華 wares in both north and south China.[134] Hard biscuit-firing was also exploited in southern China, specifically from the Yuan dynasty onwards at Ching-te-chen, when low-firing turquoise glazes were first applied to the fully fired porcelain bisque.[135]

Analysis shows that Thang dynasty *san-tshai* glazes were straightforward lead alumino-silicates that contained no baria (Table 79). Compositionally they relate in some ways to both to the first Han dynasty glaze in Table 76, and also to the lead oxide-silica-alumina eutectic mixture shown there (m.p. 650°C). They probably matured at about the same temperature as the Han glaze: that is, close to 1,000°C.

[131] One example (a large winged and horned lion with cloven feet) bearing small areas of turquoise glaze is now in the Tsui Museum, Hong Kong. See Wood (1999), p. 214, for an illustration.

[132] Satō (1981), p. 57.

[133] Rawson *et al.* (1989), p. 49. The use of a high biscuit-firing followed by a lower-temperature glaze firing was used for tin-glazed earthenwares in Renaissance times, and has been a common practice with most British and American fine ceramics since the +18th century.

[134] Wood *et al.* (1989), p. 179. *Fa-hua* can be translated as 'designs within boundaries'. Because the *fa-hua* technique uses coloured glazes applied within areas enclosed by thin lines of raised clay, many sources compare it with cloisonné metalwork. In cloisonné, enamels on copper or bronze vessels were applied within cloisons formed by raised metal wires. It has been proposed that *fa-hua* ceramics imitated cloisonné, and certainly both manner of decoration and colour schemes support this hypothesis.

[135] Liu Xinyuan (1993), pp. 34–5. Liu writes on this style (p. 35): 'a number of pieces were excavated, including an ink palette, that had obviously been destined for a second firing with a turquoise glaze.'

Table 79 *Analyses of Thang dynasty* san-tshai *glazes*

Colour	Excavation Site	PbO	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	CuO	CoO	Total
Yellow-orange	Shensi province[a]	50.5	30.5	6.9	4.9	1.2	2.1	0.2	-.-	-.-	-.-	96.3
Yellow-orange	Shensi province[b]	54.6	28.6	8.0	4.1	1.6	0.4	0.7	0.4	-.-	-.-	98.4
Yellow-orange	Fostat[c]	59.6	29.3	5.7	2.3	1.6	0.5	1.0	0.5	-.-	-.-	100.5
Green	Samarra[d]	55.6	33.6	5.8	-.-	1.0	0.5	-.-	0.3	2.0	-.-	98.8
Green	Kung-hsien, Honan province[e]	49.8	30.7	6.6	0.5	0.9	0.25	0.8	0.4	3.8	-.-	93.75
Green	Mantai, Sri Lanka[f]	55.4	32.6	6.7	-.-	0.8	0.6	0.3	0.5	3.2	-.-	100.1
White	Shensi province[g]	52.7	32.0	5.8	2.1	2.2	1.4	0.2	0.1	-.-	-.-	96.5
Blue	Kung-hsien[h]	42.1	34.4	-.-	1.1	2.3	0.5	0.3	0.1	-.-	1.2	82
Blue	Kung-hsien[i]	45.0	-.-	-.-	1.0	0.8	0.4	0.9	0.2	0.4	1.0	49.7
Eutectic mixture		61.2	31.7	7.1[j]								100.0

[a] Li Guozhen *et al.* (1986), p. 78, table 2.
[b] Rawson *et al.* (1989), p. 44, table 1.
[c] *Ibid.*
[d] *Ibid.*
[e] *Ibid.*
[f] Rawson *et al.* (1989), p. 44, table 1.
[g] Li Guozhen *et al.* (1986), p. 78.
[h] *Ibid.*
[i] Li Zhiyan & Zhang Fukang (1986), p. 69, table 1.
[j] Maynard (1980), p. 81, appendix.

It seems possible that combinations of loess with concentrated lead ores produced amber glazes, as subtraction of lead oxide from the amber glazes leaves loess-like oxide balances. When tin has been sought in Thang dynasty green glazes it has been found to be absent, which suggests a non-bronze origin for the copper pigment in the samples tested. Few specimens of cobalt-blue lead glazes have been analysed fully. One example, coming from the Kung-hsien kilns in Honan province, showed an oxide-content that suggests an unusually pure source of cobalt was available to the Kung-hsien potters, giving an almost equal-parts mixture of iron and cobalt compounds (see pp. 670–4).[136] As cobalt oxide has some ten times the colouring power of iron oxide in glazes this was a very pure material. Unlike high-temperature glazes, which can cope easily with substantial adulteration of cobalt from oxides of iron and manganese, and still give good blue glazes, lead glazes are very sensitive to impurities in cobalt ores. This strength of cobalt-content in the Kung-hsien material was therefore an essential condition for achieving successful cobalt-blue colours in such high-lead bases.

The low levels of calcia and sodium oxide present in this *san-tshai* blue glaze suggests that the cobalt was not supplied by imported cobalt-blue glass, but must have been available in a state near to an original ore. It may be that this was the same ore as used at Kung-hsien for underglaze-blue painting on some very rare late Thang dynasty white stonewares. This latter material has recently been identified as a cobalt sulphide, perhaps catterite or linneite.[137] Modern sources of cobalt sulphides exist within China, in Hopei and Kansu provinces, but a cobalt sulphide ore also occurs in the Near East at the site in Persia near to where blue-and-white wares were made in the +12th century.[138] At present, the source of cobalt ore for making Thang *san-tshai* blue glazes remains obscure.

Liao Dynasty Lead Glazes

The Liao empire, with its southern borders near to China's Great Wall, and much of its ancient territory in present-day Inner Mongolia and Liaoning province, borrowed many forms and glazes from the old Thang dynasty *san-tshai* tradition. Liao dynasty potters also created some very distinguished *san-tshai* wares of their own, making imaginative use of uncoloured cream-white areas and also complex 'repoussé' decoration in the style of silverware and achieved by moulding. The white slips used beneath the lead glazes showed a mineralogy consisting of pyrophyllite and kaolin, with a small amount of mica.[139] A proportion of these wares appears to have been made for everyday use.

In terms of composition, the Liao dynasty lead glazes that have been analysed seem very close to lead glazes used on *san-tshai* wares of the Thang dynasty. Like the

[136] Li Guozhen *et al.* (1986), p. 78.
[137] Chen Yaocheng *et al.* (1995b), p. 208.
[138] Kleinmann (1991), p. 334.
[139] Kuan Baozhong *et al.* (1985), p. 38.

Table 80 *Analyses of Liao dynasty lead glazes*[a]

	PbO	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	MnO	NiO	CuO	CoO	Total
Blue	43.3	42.6	10.3	0.4	0.1	1.0	0.1	0.01	0.5	0.01	0.41	0.06	0.1	98.9
Green	57.2	33.3	3.4	1.5	0.05	0.9	0.1	0.5	0.2	0.01	0.14	2.1	-.-	99.4
Amber	53.7	33.0	6.6	3.5	0.05	1.0	0.1	0.7	0.4	0.01	0.1	0.06	-.-	99.2
Green	45.95	35.9	7.4	0.7	0.01	0.5	0.1	0.5	0.2	0.01	0.02	1.4	-.-	92.7
Amber	52.7	33.6	7.1	4.0	0.04	1.1	0.1	0.4	0.3	0.02	0.07	0.2	-.-	99.6
Green	50.2	34.6	8.2	1.3	-.-	1.0	0.2	1.1	1.1	0.03	-.-	1.8	-.-	99.5
Green	56.7	33.2	4.1	0.5	-.-	0.9	0.3	1.0	0.8	0.03	-.-	1.9	-.-	99.4
Eutectic mixture	61.2	31.7	7.1											100

[a] Anon. (1988b), p. 127, table 7–5; Chen Yaocheng *et al.* (1984), p. 322, table 2.

Thang dynasty originals, the Liao glazes fall in the general area of the 650° C lead oxide-silica-alumina eutectic mixture (Table 80).

A few minor differences distinguish Thang and Liao dynasty lead glazes, mainly in the ways that their colouring oxides are used. The first glaze in Table 80 is unusual in being coloured by a nickel-cobalt mineral, rather than the iron- and iron-copper-cobalts characteristic of Thang dynasty *san-tshai* production (see also pp. 668–74). Liao dynasty green glazes tend to be richer in iron oxide, and lower in copper oxide, than those of the Thang dynasty, making them more yellow-green in tone. Liao dynasty amber glazes, however, are quite close to Thang dynasty versions. A hard biscuit-firing to about 1,120°C. has been proposed for Liao dynasty *san-tshai* earthenware and, as with the Thang wares, their body-materials were essentially underfired stonewares. The Liao dynasty glazes would have probably matured at about 1,000°C.[140]

LIAO DYNASTY BORIC-OXIDE GLAZES

All the low-fired Chinese glazes described so far in this volume have been of high-lead or lead-baria type, and have shown broadly similar compositions. However, an important exception to this principle was found at the kiln-area in the village of Lung-chhüan-wu 龍泉務 that lies north of Peking. Two sherds of Liao dynasty date from Lung-chhüan-wu, with unusual dark-green earthenware glazes, were analysed in +1989 and shown to contain boric oxide as their major glaze-flux. Their lead oxide contents were negligible, making them the earliest boric oxide-fluxed glazes so far found in the world.[141]

Boric oxide (B_2O_3) is a versatile glaze material that can operate variously as a flux, a glass former and a glaze stabiliser. In large quantities it may cause crazing, while in smaller amounts it tends to reduce crazing, the so-called 'boric oxide anomaly'.[142] Its refractive index is lower than that of lead oxide, so boric oxide glazes tend to lack the richness of their lead equivalents. Their response to colouring oxides lies midway between alkaline glazes and lead glazes. For example, when copper oxide is used in boric-oxide glazes it gives a greenish-blue colour, rather than the turquoise-blue characteristic of high-alkali glazes, or the strong emerald-greens typical of glazes that are rich in lead.

In terms of their chemistries and their original recipes, these glaze analyses from Lung-chhüan-wu are hard to interpret (Table 81). No eutectic basis is apparent in the glazes, and it is also hard to identify any natural raw materials that might have been used to make them. The most abundant boron-rich mineral found in Liaoning province today is ascherite, a magnesium borate, but ascherite is too high in magnesium to have been used in the published recipes.[143]

[140] Kuan Baozhong *et al.* (1985), p. 38.
[141] Chen Yaocheng *et al.* (1989c), pp. 317–21.
[142] Singer & Singer (1963), pp. 208–11. The anomaly occurs when Boron-Oxygen bonds change from threefold to fourfold co-ordination.
[143] Travis & Cocks (1984), p. 113.

Table 81 *Liao dynasty boracic earthenware glazes and bodies from Lung-chhüan-wu*[a]

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	PbO	B_2O_3	CuO	MnO	P_2O_5	Total
Liao boracic glaze 1	58.1	9.3	0.8	4.6	0.6	3.1	5.1	1.3	10.3	6.4	0.04	-.-	99.6
Liao boracic glaze 2	54.7	5.5	0.6	6.2	2.0	1.5	10.5	0.4	12.8	6.3	-.-	0.2	100.7
Boracic glaze body 1	57.1	32.9	1.6	0.6	0.2	1.7	4.0	-.-	-.-	-.-	0.01	0.1	98.2
Boracic glaze body 2	58.6	32.2	1.6	0.5	0.2	1.9	3.1	-.-	-.-	-.-	-.-	0.1	98.2

[a] Chen Yaocheng *et al.* (1989), pp. 317–21.

A possible candidate as a source of boric oxide in these glazes might be ulexite ($Na_2O.2CaO.5B_2O_3.16H_2O$), a material rich in boric oxide, soda and calcia, the three main fluxes in the above analyses. Glaze 1 could have been made with a mixture of a typical ulexite material 28.5, feldspar 46.5, quartz 18.5 and copper oxide 5.5. Unfortunately these raw materials will not 'fit' Glaze 2 as the glaze is too rich in sodium oxide and too low in alumina to have used ulexite alone. However, a mixture of ulexite 32, soda ash 14, quartz 37, China clay 11 and copper oxide 5 would 'rebuild' Glaze 2, as would mixtures of raw borax 35, soda ash 9.5, quartz 31, clay 9 and copper oxide 6. In short, Glaze 2 can only be made using soluble raw materials, which suggests that some of the original Liao boric-oxide glazes may have been fritted. Another oddity of these glazes is seen in the high percentages of cupric oxide (av. 6% CuO) that they contain. This is about three times the amount of copper found in typical Liao dynasty green lead glazes.[144]

Despite the importance of these glazes in the history of world ceramics, and their great rarity in China itself, their appearance was actually rather undistinguished, and boric-oxide glazes do not seem to have been developed further at this time. The Chinese researchers who studied the glazes suggest that the huge demand for glazed tiles for temples and palaces in Peking may have stimulated experiment with these new earthenware compositions, and they propose borax as the most likely source of B_2O_3.[145]

SUNG AND CHIN DYNASTY *SAN-TSHAI*

One of the most obvious practical influences of ceramic techniques on Chinese craftsmen during the Liao dynasty was the reappearance in China of lead-glazed wares for everyday use. The cobalt-blue glaze had now all but disappeared from the palette, but the three basic *san-tshai* colours of straw, amber and green had survived. The elaborate resist and 'mosaic' techniques of traditional Thang dynasty *san-tshai* were abandoned in the Sung and Chin dynasties. In their place was employed a technique that became fashionable in the late Liao dynasty, namely the infilling of *sgraffito* patterns on light-firing clays or slips, with coloured glazes. This technique resulted in some fine objects, particularly noteworthy being ceramic pillows made at Tzhu-chou kilns 磁州窯 in northern China. Analyses of Sung and Chin Tzhu-chou lead glazes are scarce, but one that is available gives results that are very similar to Liao glazes (Table 82).

As with Thang and Liao dynasty *san-tshai*, the Sung and Chin dynasty Tzhu-chou glazes were applied to light-coloured, underfired stoneware bodies, and then glaze-fired to about 1,000°C. In addition to the standard colours of yellow, green and amber, Sung dynasty *san-tshai* wares can also show occasional use of turquoise-blue, dark iron-red, and what may well be an iron-manganese purplish-brown. Full analyses of these latter three colours have yet to be made.

[144] Wood (1999), pp. 207–9.
[145] Chen Yaocheng *et al.* (1989c), p. 317.

Table 82 *Analyses of Sung and Liao dynasty* san-tshai *green glazes*

	PbO	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	CuO	Total
Sung dynasty *san-tshai* green glaze[a]	54.8	32.3	4.8	1.1	2.2	0.5	0.65	0.3	2.8	99.45
Liao dynasty *san-tshai* green glaze[b]	57.2	33.3	3.4	1.5	0.9	0.1	0.5	0.2	2.1	99.2

[a] Anon. (1988b), Borax Consolidated Limited, p. 126, table 7–4.
[b] *Ibid.*, p. 127, table 7–5.

Table 83 *Analyses of lead glazes from south China (n.d. = not determined)*

	PbO	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	CuO	P_2O_5	SnO_2	Total
Chhiung-lai green[a]	58.8	29.5	0.4	5.6	0.7	0.6	0.3	0.6	0.25	1.5	0.1	n.d.	98.4
Chhiung-lai yellow[b]	50.2	36.2	0.6	10.1	1.1	0.4	0.5	0.6	0.3	n.d.	0.04	n.d	100.0
Chi-chou green[c]	47.0	36.6	0.3	5.4	0.8	2.8	0.6	1.4	0.2	2.3	n.d.	2.45	99.9

[a] Zhang Fukang (1989), p. 64, table 2.
[b] *Ibid.*
[c] Zhang Fukang (1985b), p. 59 and data from poster-paper. See also Hughes-Stanton & Kerr (1980) p. 52 and sherds 265 and 267.

SOUTHERN LEAD GLAZES

Most low-fired glazes were made in north China, where they saw their earliest and most rapid development. However, a few lead glazes were produced in the south of the country, from the Thang dynasty onwards, most notably at Chi-chou 吉州 in Chiangsi province, and at Chhiung-lai 邛崍 in Szechuan province. Green lead glazes were the most popular colour, and a few examples of southern *san-tshai* glazes have been analysed and published. They have compositions similar to those used in north China and, like the northern glazes, were applied to underfired stoneware clays, often coated with white slips, rather than to true earthenware bodies (Table 83).

The tin oxide content of the Chi-chou glaze is particularly high. It may represent the use of high-tin scrap bronze in the glaze recipe or, just possibly, a copper-tin sulphide ore (copper-tin pyrites).

LEAD GLAZES AND ARCHITECTURAL CERAMICS IN THE SUNG AND CHIN DYNASTIES

In the Sung dynasty, official production of architectural ceramics was well documented. The Eight Eastern and Western Works Bureaux (Tung Hsi Pa Tso Ssu 東西八作司) organised under the Directorate for the Palace Buildings (Chiang-tso Chien 將作監) supervised building works both inside and outside the walls of the capital.[146] Official production was not continuous at this period, however. Kilns were activated when materials were needed, for example for eight months between the second and tenth months of +1009 while Emperor Cheng-Tsung's Palace of Accomplished Radiance (*Chao-ying Kung* 昭應宮) was being erected.[147]

The bureaux would also have managed an order given by Emperor Hui-Tsung (*r.* +1101–25), for green-glazed tiles for the construction of the palace Hall for Establishing Brilliance (*Chien-ming Thang* 建明堂).[148] Archaeological evidence for the scale of imperial building is indicated by finds such as those from Thang-kung Chung-lu 唐宮中路, a major palace site at the Northern Sung dynasty 'western capital' of Lo-yang. Quantities of excavated, unglazed bricks and tiles included tiles with stamped marks indicating different on-site kilns in which they had been fired.[149]

For both the Sung and Chin dynasties, there is a wealth of extant tiled buildings to demonstrate the strength of architectural ceramic manufacturing. In Shansi province, for example, since the Northern Wei period an important centre for glazed tilework, archaeological and temple restoration work has confirmed the existence of several important monuments. At Thai-yüan 太原 tiles dating to +1029, with green and yellow glazes and grey-black bodies, have been identified at the Fang-lin temple 芳林寺. The earliest portions of the Temple of the Holy Mother (*Sheng-mu Ssu* 聖母寺) at Thai-yüan date to +1102, and a tile with a workman's name has been found there. Pipe tiles dating to +1087 adorned the upper Hall of the Three Purities (*San-chhing Lou* 三清樓) at Chieh-hsiu, in Shansi.[150]

Even more tiles survive from the Chin dynasty, many of them complete and *in situ*. One fine example is the Temple of Sublime Prosperity (*Mi-tho Tien* 彌陀殿) at Shuo-hsien 朔縣, erected in +1143, with tilework dated by inscription to +1146. Its roof still bears *chhih-wei* 鴟尾 finials and heroic guardian and beast figures, with reddish bodies and brilliant green and yellow glazes.[151]

Patrons and potters both had their names inscribed on important objects. In +1982 a *san-tshai* incense burner of exceptional size and quality was excavated at Li-shih-chheng 离石城 in western Shansi. It was signed by a potter called Chu Chheng 朱成, had a cyclical date equivalent to +989 or +1049, and between the two

[146] *Sung Shih*, ch. 185, p. 22. *Sung Hui Yao Chi Kao*, ch. 30 ('*Chih Kuan*'), p. 7. Hucker (1985), p. 140.
[147] *Sung Hui Yao Chi Kao*, ch. 55 ('*Shih Huo*'), p. 20.
[148] *Sung Shih*, ch. 101 ('*Li Chih*'), p. 11.
[149] The sealmarks read 'southern kiln' (*nan yao* 南窯), 'northern kiln' (*pei yao* 北窯), 'western kiln' (*hsi yao* 西窯) etc., see Anon. (1999d), pp. 40–2, pls. 4, 7.
[150] Chhai Tse-Chün (1991), pp. 7–8.
[151] *Ibid.*, pp. 10–11.

handles was carved the name 'Hu Yen 呼延'. This identified the censer with an important and gallant Sung dynasty general who subsequently lent his name to opera and plays. Hu Yen received many honours for his bravery and loyalty as a soldier, but was disgraced by his son. Family honour was restored by his grandson, who returned to make ritual offerings at the family tombs. The censer could therefore either have been made for Hu Yen at the height of his glory (+989) or for his grandson's ceremonial use (+1049).[152]

The late Northern Sung dynasty monograph *Ying Tsao Fa Shih* describes technical processes in brick- and tile-making. Compiled by Li Chieh 李誡 in +1097, it was printed in +1103 and reprinted soon afterwards in +1145.[153] *Chüan* 15 describes forming processes for tiles, that appear similar to those carried out by specialist artisans in the +5th century (see p. 499). Fine clay without grit, used for both ordinary tiles and those with attached figures, was prepared. The next day the wedged clay was placed on a slow wheel and shaped around a circular wooden form with adjustable diameter, ash or lime-dust (*hui* 灰) acting as a separator. The clay was covered with cloth steeped in slip. After the circular tiles were leatherhard, four divisions were marked with a knife and the marking lines highlighted with water before being left to dry further, and subsequently divided.[154] Square bricks and long strip-tiles were also made in wooden forms.

Dried tiles were smoothed with a tile-stone and wet cloth to remove fabric markings, and were then given a water-smoking firing. First their surfaces were dressed with a mixture of quartz sand and soft soil or talc. Then the water-smoking phase was accomplished using dried grasses, followed by mugwort (*kao-tshao* 藁草), pine and cedar wood, goat droppings and hemp oil.[155] Then the tiles received their full reduction-firing. The whole process took seven days: on the first day the kiln was loaded, on the second fired up, on the third water was trickled in, the kiln was left to cool for three days and was unloaded on the seventh.[156] The kiln was a domed structure with thick buttressing walls (*lei-tsao yao* 壘造窯) with a central chimney.[157]

Lead glazing was carried out using lead oxide, which was prepared by combining black lead (*hei-hsi* 黑錫) with potassium nitrate KNO_3 (*phen-hsiao* 盆硝) and heating them together in an iron pot for a day.[158] The resulting substance was ground into

[152] *Ibid.*, pp. 6–7. *Sung Shih*, ch. 279 ('Lieh Chüan:38'), pp. 9488–89.

[153] *Ying Tsao Fa Shih* is discussed in Needham *et al.* (1971), pp. 107–10, where a list of chapter contents is included.

[154] *Thien Kung Khai Wu*, ch. 7, p. 1b, gives an almost identical description of tile-making save that it adds that when the cylinders of clay had dried a little, the clay was removed from around the mould and naturally fell apart into four pieces.

[155] *Ying Tsao Fa Shih*, ch. 15, pp. 105–11. Li Chhüan-Chhing & Liu Chien-Yeh (1987), pp. 13–14. See also Chhen Ming-Ta (1981).

[156] *Ying Tsao Fa Shih*, ch. 15, p. 111. Li Chhüan-Chhing & Liu Chien-Yeh (1987), pp. 21–3, interpret this to mean that the firing only lasted five days, which does not agree with our interpretation of the text.

[157] *Ying Tsao Fa Shih*, ch. 15, pp. 111–12. Li Chhüan-Chhing & Liu Chien-Yeh (1987), p. 10, interpret this description as that for the glazing kiln.

[158] An analogous process is described in Vogt (1909), pp. 587–8.



Fig. 138 Making tiles, from *Thien Kung Khai Wu* (+1637)

powder and reheated in an enclosed container covered with a brick lid for another two days. The material was then pulverised and mixed with quartz, copper powder (for colour) and water (hot water in winter), and applied to tiles.[159] The glazing kiln (*liu-li yao* 琉璃窯) was filled, fired up on the second day, left to cool and emptied on the fifth day.[160]

[159] *Ying Tsao Fa Shih*, ch. 15, p. 110; Li Chhüan-Chhing & Liu Chien-Yeh (1987), p. 17.
[160] *Ying Tsao Fa Shih*, ch. 15, p. 111.

From the earliest times that tiles were made, some of the best products were destined for the rulers of China. The Yuan dynasty emperors commissioned impressive architectural monuments. Their palace buildings at the capital Ta-tu (Peking) have been excavated.[161] *Yuan Shih* (History of the Yuan Dynasty, +1370) mentions four kiln sites in Ta-tu where plain white architectural ceramics were made, organised under the Directorate For Imperial Manufactories (*Shao-fu Chien* 少府監). These were important kilns employing more than 300 artisans each, under the direction of a Commissioner and Assistant Commissioner. There was also the Porcelain Service (*Liu-li Chü* 琉璃局), established in +1267, that supervised coloured ceramics.[162] A Yuan dynasty kiln site making both white-glazed bricks and *liu-li* architectural components was excavated in the Hai-tien district 海澱區 of north-west Peking in +1983. It has been suggested that it was one of the kilns listed in the official history.[163]

Yuan dynasty temple buildings with tiled roofs have survived, among them several sites in Shansi province.[164] Shansi provided the central government with considerable revenue in tax from ceramics at that period. For example, *Yuan Shih* recorded that in +1328 Thai-yüan alone yielded 58 ingots'-worth of taxes.[165] Kilns were flourishing, and introduced innovatory techniques and styles. A significant feature of Yuan period tiles was the use of a broader palette of colours, typified by turquoise, a colour that had first been used with limited success during the Thang dynasty (see pp. 622–31).

Turquoise was used both on stoneware bodies and on porcelain. The most notable turquoise-glazed porcelain was that excavated from Yuan dynasty strata of the imperial kiln site at Ching-te-chen.[166] In addition, the Yuan dynasty saw the beginnings of the decoration called *fa-hua* 琺華 (see above p. 501). Recent research in China suggests that *fa-hua* ceramics were first produced in Shansi province in the Yuan dynasty, as a by-product of the tilework business.[167] It is difficult, however, to attribute Yuan dynasty dates to known artefacts. By the Yung-Le reign period of the Ming dynasty, *fa-hua* vessels were being made in the environs of Ping-yang 平陽 (modern Lin-fen 臨汾) in southern Shansi province. Later in the +15th century, fine-quality *fa-hua* pieces were made in several kilns in the south-eastern corner of Shansi. Kilns around Yung-chi 永濟 and Hsin-chiang 新絳 in the south-western toe of Shansi specialised in the production of figures. All these products used stoneware bodies. At some time in the +15th century porcelain kilns in south China, probably at Ching-te-chen, started to manufacture porcelain *fa-hua* vessels. Like the

[161] Anon. (1972a), pp. 19–28, pls. 8 and 9.
[162] *Yuan Shih*, ch. 90 ('*Pai Kuan chih*'), p. 2881. Hucker (1985), pp. 318, 415. Factories for lead-glazed tiles were established in Peking as early as the Liao and Chin periods, as both textual references and excavated artefacts make clear, cf. Chao Kuang-Lin & Liu Shu-Lin (1997), pp. 151–3.
[163] Zhao Guanglin (1985), pp. 91–2.
[164] See Chhai Tse-Chün (1991), pp. 12–17.
[165] *Yuan Shih*, ch. 94 ('*Shih Huo Chih*'), p. 31. Cf. Otagi Matsuo (1987), pp. 342–5.
[166] Liu Xinyuan (1993), pp. 33–4.
[167] Chhai Tse-Chün (1991), p. 19.



Fig. 139 Ridge-tile figure with turquoise glaze at the Yung-Le Kung 永樂宮 in Shansi province, Yuan dynasty

northern wares, they had a limited range of shapes and favoured complicated decorative schemes. For a discussion of *fa-hua* glaze technology, see pp. 628–31 and 681–2.

In the Ming and Chhing dynasties, during long periods when society was relatively stable, huge numbers of tiles were commissioned for court buildings, temples and tombs. As tile-making did not require large, high-temperature kilns, potteries could be set up close to where building or refurbishing work was being carried out. We know that many imperial manufactories were set up in the Ming and Chhing dynasties; for example, at Lin-chhing 臨清 and Wu-chhing 武清 in Shantung, at Su-chou 蘇州 in Chiangsu, at Tshai-chou 蔡州 in Honan, in the Western hills near Peking,[168] in the mountains near Shen-yang 瀋陽, in Liu-li-chhang 琉璃廠 in Peking, and in Chü-pao-shan 聚寶山 outside the Chung-hua city gate 中華門 at Nanking 南京.[169] The Nanking kilns were established in +1393, and it is reported that no less than 72 kilns were needed for the building of the Ming capital there in the +14th century.[170] They used fine white clay from Pai-yün-shan 白云山 (White Cloud Mountain, also known as White Clay Mountain, Pai-thu-shan 白土山) in Tang-thu county 當塗縣, Anhui province.[171]

Fine clay from Anhui province was transported over great distances to the capital city throughout the Ming dynasty. Materials for the imperial mausolea of the Hung-Wu emperor's ancestors have been found at tile kilns in Tang-thu county in Anhui.[172] In +1406 bricks and tiles fired in Peking used clay brought some 3,000 *li* by boat from there. As late as the +17th century, white clay from Anhui was used for imperial tiles, and in the construction of imperial mausolea in Hupei province.[173] It was not until the Chhing dynasty that clay was collected from Men-thou-kou 門頭溝 district, near Peking.[174]

Early Ming dynasty tiles were principally stoneware with low-firing lead glazes. Four important exceptions dating to the Hung-Wu, Yung-Le and Hsüan-Te reign periods have so far been found. The first was high-fired, underglaze-red decorated porcelain tiles from the Hung-Wu period palace site at Nanking, and the imperial ancestral home in Anhui province. The second was black-glazed tiles of the Hung-Wu period excavated at Ching-te-chen in +1990. The third was plain white porcelain tiles from the Pao-en temple 報恩寺, and the fourth underglaze-blue decorated tiles from the imperial kiln site at Ching-te-chen.

[168] *Tung Kuan Chi Shih*, pp. 3–4, 23.
[169] *Ta Ming Hui Tien*, ch. 190, p. 1.
[170] Zhang Pusheng (1991), p. 62.
[171] *Thien Kung Khai Wu*, ch. 7, p. 2a. *Thai-phing Fu Chih* (1531 edn), ch. 13 ('*Wu Chhan*'), quoted in *Tang-thu Hsien Chih* (1571 edn), ch. 8, p. 156. For a discussion of white-clay mining in Anhui province, see p. 237.
[172] Harrison-Hall (2001), p. 516. Tiles from Pao-en temple 報恩寺 in the British Museum, that may have been fired at Tang-thu in Anhui, are illustrated in pls. 18.11–18.17 (pp. 524–8).
[173] *Ta Ming Hui Tien*, ch. 181, p. 1. *Thien Kung Khai Wu*, ch. 7, p. 2a.
[174] Men-thou-kou had been making ceramics at least as early as the Liao dynasty, see p. 500.



Fig. 140 Fragment of tile with underglaze-copper-red dragon design, from the site of the Ming dynasty palace

The Hung-Wu palace finds comprised five incomplete circular end tiles with moulded relief dragon design, and eleven incomplete shaped end tiles with phoenix patterns. All had their designs painted in underglaze copper-red, and were fired in high-temperature kilns at Ching-te-chen. The emperor's ancestral home in the Ming royal city in Feng-yang county 風陽縣 in Anhui, built in +1378, also yielded end tiles decorated with dragons in underglaze-red.[175]

Two partially black-glazed tiles made under personal supervision were excavated at the Chu-shan (Pearl Hill) imperial kiln site in Ching-te-chen. Archaeologists speculate that they may have been part of material supplied by that kiln for the construction of the Altar for the Gods of Soil and Grain 土穀祈壇 in +1377. These tiles also record the names of the supervisor, foreman, group foreman, glazer, firer and batch reference number.[176]

More than 2,250 white porcelain L-shaped bricks have been unearthed from the Yung-Le period stratum at the imperial kiln site at Ching-te-chen. Many similar tiles, picked up in the vicinity of Nanking, exist in museum collections worldwide. Research has identified the bricks as being identical to those used to face the Pao-en temple 報恩寺, known to Westerners as the 'Nanking pagoda'. This temple was

[175] Zhang Pusheng (1991), pp. 62–3.
[176] Harrison-Hall (2000), p. 516.

built by order of the Yung-Le emperor in memory of his deceased parents and mainly constructed between +1412 and +1431.[177]

Hsüan-Te period porcelain tiles painted beneath the glaze with cobalt-blue have been found on two occasions on the site of the imperial factory. The tiles, some solid and some hollow, appear from their form to have been employed as decorative friezes, though their use is unconfirmed in any texts.[178]

Another significant type of tile, this one unglazed, was the so-called 'golden brick' or 'metal brick' (*chin-chuan* 金磚) made at Su-chou. Mentioned in several Ming texts,[179] their name derives from the fact that they were so finely formed and fired that they had a hard, metallic ring when struck. In fact, the tiles were black owing to carbonisation of the outer layers (see p. 296). They provided flooring for the three main halls of the palace in Peking, constructed between +1407 and +1420. An officer in the Ministry of Works in charge of brick-making at Su-chou, Chang Wen-Chih 張問之, described their meticulous preparation and construction in a later text called *Tsao Chuan Wa Thu Shuo* (Illustrated Account of Brick Making). Chang was responsible for 63 families of potters, who used light golden-yellow clay from Lu-mu 陸墓 in the north-east of the city to make oblong bricks 2.2 × 1.7 feet (*chhih* 尺). The clay was prepared for use in seven stages: digging, transporting, drying, pulverising, crushing, grinding and sieving. Then it was washed and refined in six stages, first in three-chambered tanks, then filtered in triple-layer net, spread on the ground to dry, when dry it was packed into cloth sacks, tied with iron wire, and trodden. Then the clay was worked by hand, pulverised in a stone mortar, pounded with wooden hammers and again dried in the shade. The material was gently worked by hand every day thereafter for eight months, until it was ready for forming. Quick firing was avoided in the first stage of kiln-firing. Initially, the brick bodies were heated and smoked with chaff and straw for the first month, with firewood for the second month, with logs for the third month and finally with pine-wood for the last 40 days. After 130 days firing the bricks were cooled gradually by introducing water through the kiln roof. Quality testing of the finished bricks was exacting and production quotas so huge that suicides occurred among the potters when batches failed.[180]

What was described was the laborious refinement of particular raw clay materials, and their very slow, careful firing. This gave rise to bricks of exceptional density

[177] Pao-en temple and its glazed pagoda reportedly cost the court 2.5 million ounces of silver and involved more than 100,000 builders and guards. The pagoda tower was 80 metres high, and was completed by +1419. It consisted of nine storeys and had 72 arched doorways of colour-glazed tiles; for in addition to the unusual white porcelain bricks, decorative features were clad in stoneware tiles with the usual range of coloured lead glazes. The complex was razed to the ground in +1854 during the rebellion by the Thai-phing 太平天國, but certain records of its existence remain. There are Western engravings made shortly before its destruction, and extant bricks in museum collections. See Hobson (1915), pp. 202–5; Liu Hsin-Yüan (1989), pp. 20–1, 61; Kerr (1992), pp. 56–7; Grace Wong (1994), pp. 28–31.

[178] Liu Hsin-Yüan *et al.* (1998), pp. 122, 173.

[179] For example, *Ku Su Chih*, ch. 14, p. 33, *Tung Kuan Chi Shu*, p. 1, *Thien Kung Khai Wu*, ch. 7, p. 4a.

[180] *Tsao Chuan Wa Thu Shuo* 造磚瓦圖說, in *Chhin Ting Ssu Khu Chhüan Shu Tsung Mu Thi Yao*, ch. 84. Cf. Needham *et al.* (1971), p. 42.

and strength. The recipe for making golden bricks was lost at the end of the Chhing dynasty, and recent attempts to imitate their manufacture concentrated on five factors: raw materials, processing, forming, drying and sintering. The microstructure of extant golden bricks was analysed, and clay materials with comparable chemical composition, particle size, shrinkage and plasticity were selected. Such clays had fine grains, few impurities, good plasticity, a reasonably high melting-point and a wide firing range. They needed to be extremely finely processed (like porcelain clays) to ensure fine particle size, purity, homogeneous water distribution and few pores. Careful forming ensured dense structure as well as good appearance. Careful drying and firing meant less danger of warping or cracking, and it was found that a relatively high-firing temperature range of 1,100–1,210°C gave the best results. The firing process was lengthy, but not as long as 130 days![181]

Imperial construction projects used bricks and tiles from government-owned kilns in various provinces. Skilled workers employed there included those specialising in refining clay with water, mixing clay, reconstructing kilns, loading kilns and every other process. Architectural ceramics were fired twice, the first time as unglazed blanks, the second in muffle kilns with glaze. Enormous quantities of wood were burnt, with single large tiles weighing up to 60 *chin* 斤 (about 35 kilograms) consuming the most of all.[182] In the middle and late Ming dynasty demands for massive architectural elements increased, and huge multi-coloured items in complex openwork forms tested the skills of the potters to the limit.[183] Such was the scale of imperial building that kilns were often short of labour, and soldiers were dispatched to lend a hand.[184] *Ming Shih* (History of the Ming Dynasty, +1739) notes that the middle years of the Chia-Ching reign period were a boom period for building work on palace buildings.[185] Heavy bricks and tiles were transported back to the capital by whatever kind of boat could be pressed into use: passenger boats, grain transporters, private barges etc.[186] In the second year of the Wan-Li reign period (+1574), special kilns were established at Ching-te-chen to make 300,000 bricks for the city, everyone in the city contributing a small amount of funds.[187]

In part, the florescence of the building trades in the +16th century reflected a general period of prosperity and expansion,[188] during which new palaces were built. It was also a time when extensive repairs were carried out to old or damaged

[181] Yang Wuhua *et al.* (1989), Yang Wuhua *et al.* (1995).
[182] *Kung Pu Chhang Khu Hsii Chih*, ch. 5, p. 23, cf. *Thien Kung Khai Wu*, ch. 7, p. 2a.
[183] *Ta Ming Hui Tien*, ch. 187, p. 56.
[184] For example, in +1427 5,000 troops were sent to fire bricks in kilns in Shantung and Honan provinces, with fifteen officials to supervise them, *Ta Ming Hui Tien*, ch. 190, p. 1.
[185] *Chung-Kuo Li-Tai Shih-Huo-Chih Cheng-Pien*, vol. 2, p. 942. *Thien Kung Khai Wu*, ch. 7, p. 3b, also detailed a large factory for the making of imperial bricks at Lin-chhing 臨清 in Shantung province, and the manufacture of good-quality square bricks at Su-chou. Both texts mention the Black Kilns, official manufactories for unglazed bricks and tiles administered by the Ministry of Works 公部, as does *Ta Ming Hui Tien*, ch. 190, pp. 1–6, which also mentions the urgent need for bricks for lots of large buildings in +1530.
[186] *Ta Ming Hui Tien*, ch. 190, p. 2.
[187] *Ibid.*, ch. 190, p. 3.
[188] Ray Huang (1969), p. 110.

structures. A monograph that paid homage to one man's efforts in managing such projects was *Tung Kuan Chi Shu* ('Chronicle of the Winter Office', +1616).[189] This tributary tome records the achievements of a man called Ho Sheng-Jui 賀生瑞,[190] who supervised construction of two palaces in the Forbidden City and renovated three halls, after the great conflagrations of +1596 and +1597.[191]

The monograph recorded in detail the materials needed for construction and the cost of everything, for Ho Sheng-Jui's great achievement was that he saved over 370,000 *liang* 兩 of silver, spending only just over 630,000 of the 1,000,000 *liang* allocated for the projects.[192] Hardwood came from Szechuan, Hunan and Kweichow provinces, and special golden bricks from Su-chou. Su-chou also consigned square bricks, but on investigation of over 10,000 at the factory, these were found to be substandard. They were red in colour and made of coarse clay, and were said not to be as good as bricks made there previously.[193] The total number of bricks and tiles fired for the two palaces was 1,700,000, of which 97,000 were used; three separate kilns in the Peking city area manufactured them.[194] The kilns were at Lin-chhing 臨清, Wu-chhing 武清 and Thung-chou 通州, and were supervised by court officials. Work on this scale demanded an enormous input of both labour and official supervision. 1,000 imperial guards were dispatched, 300 to monitor the kilns making black bricks, and 700 for the kilns making colour-glazed tiles.[195] Corruption was, as ever, a factor. Many false claims were made by the potters, while the officials claimed for recruiting more workers than requested.[196] The manager of the colour-glazed tile kilns was a eunuch called Liu Chheng 劉成, who claimed to have spent vast sums of money checking the colours of finished bricks and tiles. Supervisor Ho Sheng-Jui refused to pay.[197] Quality control was very strict. Each type of tile was fired and two samples sent for royal inspection. One was left before the emperor, the other for the Supervisor as a test standard. Subsequent deliveries were compared with the standard, and refused if of lesser quality.[198] Supervisor Ho battled

[189] The name *Tung Kuan* 冬官 'Winter Office' is an unofficial, archaic reference to the Ministry of Works. Hucker (1985), p. 552.

[190] The chronicle was by his son, who wrote in the first preface (p. 1) that his honoured father's long training and loyal service were not appreciated in his lifetime, nor were his trials and tribulations remembered in official records.

[191] The palaces were that of Heavenly Purity (*Chhien-chhing Kung* 乾清宮) and Earthly Repose (*Khun-ning Kung* 坤寧宮), two of the main buildings of the Three Rear Halls that constituted the imperial living quarters. The Palace of Heavenly Purity contained the sleeping chambers of Ming emperors, but during the Chhing was converted for formal living and office space. It was also the palace where emperors lay in state immediately after death. The Palace of Earthly Repose served as sleeping quarters for Ming empresses, but during the Chhing was used for daily observances of the Manchu native religion. Its east wing was the wedding chamber for Chhing emperors who married after ascending the throne (Khang-Hsi, Thung-Chih and Kuang-Hsü). See Weng Wan-Go & Yang Boda (1982), pp. 50–7. For another interpretation of items from *Tung Kuan Chi Shih* see Ruitenbeek (1998), pp. 202–8.

[192] *Tung Kuan Chi Shih*, p. 22.

[193] *Ibid.*, p. 7.

[194] *Ibid.*, pp. 3–4.

[195] *Ibid.*, p. 11.

[196] *Ibid.*, p. 14.

[197] *Ibid.*, p. 16.

[198] *Ibid.*, p. 11.

hard to keep expenses down. One of his most notable victories concerned the manufacture of flat tiles made in official kilns (*kuan-wa* 官瓦). Palace eunuchs, relying on hallowed tradition and the pretence of keeping official kilns in work, had profited greatly from monopoly manufacture, even though tiles obtainable from private kilns (*min-wa* 民瓦) were much cheaper and of better, whiter material. Supervisor Ho secretly ordered 1,000 samples of each type to be made and sent for official inspection. A compromise was reached, whereby official and private kilns supplied half the numbers of tiles each, and a great deal of money was saved.[199]

The middle years of the Ming dynasty marked the apogee for private tile businesses. For example, tile kilns brought wealth and importance to Shansi province, where 93 sites have been documented by means of tile inscriptions.[200] Major temples were clustered along river valleys, and significant finds included religious images, incense burners, flower vases and models of temple lions as well as wall and roof tiles. Tilework employment was controlled by a limited number of clans, trade being handed down from father to son. Businesses in Chieh-hsiu in central Shansi and Yang-chheng 陽城 to the south employed the largest number of workers and continued lines of family succession for the longest periods. The Chhiao clan 喬氏 from Yang-chheng was the most famous family tile firm. Other important tile- producing centres were Thai-yüan, Wen-shui 文水 and Shou-yang 壽陽, the latter two towns producing products celebrated for their quality. Inscriptions on tiles provided proof that workers from Hsiu-wu 修武 in Honan, Chhao-pa 朝吧 in Shensi and Cheng-ting 正定 in Hopei province also worked in Shansi province. This is because major tilework businesses in north China tended to cluster together, and the three sites mentioned were all just over Shansi's borders to the south, west and east.[201]

A decline in business started at the tile kilns in Shansi province in the Thien-Chhi reign period and continued until about +1680, throughout the period of civil war that accompanied the transfer of power from the Ming to the Chhing dynasty. Nonetheless, dated tiles attest to the fact that some business continued to be carried out during these troubled years. Recovery in the period +1680–1800 led to further expansion in the industry, the creation of fine monuments and a legacy of numerous sites with tiles over a very broad area, the latest find dating to +1907. Many of the old firms were still in business, while a few new names like the Su clan 蘇氏 of Thai-yüan prospered.[202] Another period of recession set in during the early +19th century, and a lowering of standards among tile producers followed. In spite of this, a few major commissions to tile temple roofs resulted in pleasing effects during the mid to late +19th century. Even in the very last years of the Chhing dynasty, tile factories were reproducing items in a Ming dynasty style whose shapes, patterns and colours were quite acceptable to customers.[203]

[199] *Ibid.*, p. 20.
[200] Chhai Tse-Chün (1991), pp. 18, 34–8.
[201] *Ibid.*, p. 39.
[202] *Ibid.*, p. 51.
[203] For Shansi province, see *ibid.*, pp. 40–51.



Fig. 141 Detail of a roof decoration using plaster mosaic from a temple near Taipei 臺北, Taiwan 臺灣, +20th century

In south China, the picture was slightly different. Early tile kilns established to satisfy the building needs of rulers in Kuangtung and northern Fukien provinces in the Han dynasty have been mentioned on p. 114. Princely styles in building tended to follow traditions established further north, with local variations. This was the case when the second kingdom of Min 閩國 was established in northern Fukien province, in the Five Dynasties period. Brothers of the princely Wang clan 王氏 from Honan province established their capital in Fu-chou 福州 and started a massive building programme. Several kilns were set up in the northern suburbs, and they made a variety of unglazed tiles, bricks and other architectural components. Little is left of the +10th-century buildings, but that frenetic period of activity is

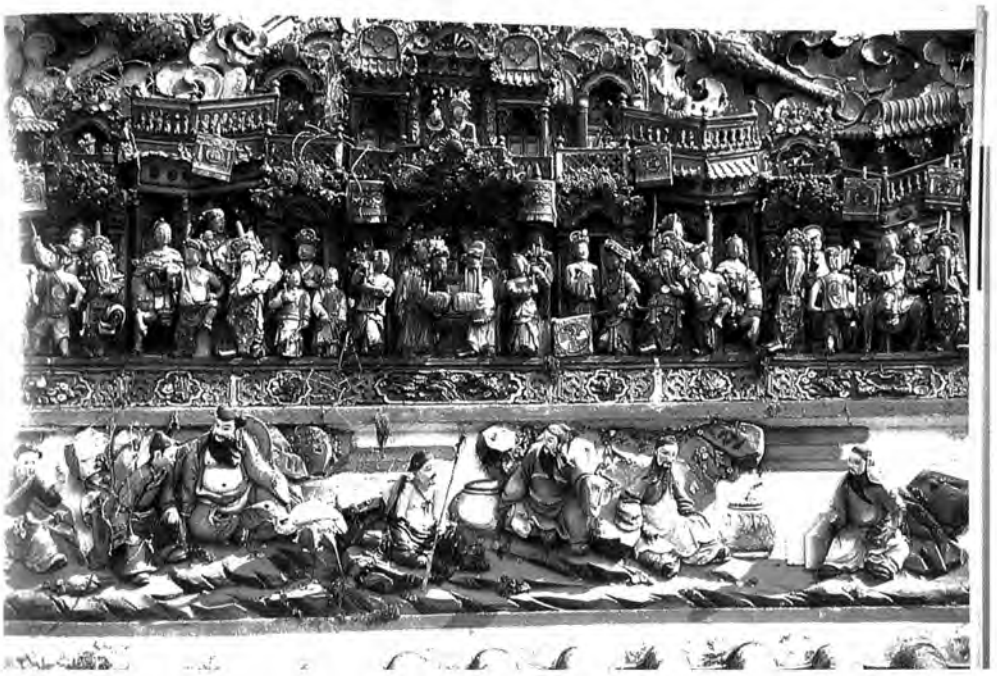


Fig. 142 Detail of the roof decoration in the Chinese temple in Saigon, Vietnam, +1997

remembered in the historical record through texts such as *Shih Kuo Chhun Chhiu* (History of the Ten Kingdoms Period, +1669) and *San Shan Chih* (History of the Three Mountains, *c.* +1150–87).[204]

Demand for tiles fluctuated according to economic and construction activity. One case in which demand exceeded supply led, in the +17th century, to the substitution of plaster mosaic sculpture for tiles. Plaster mosaic sculpture used ceramic and glass fragments inset into a ground to produce dramatic effects at a cheaper price than tilework. It was also easier to repair. Thus it came to dominate architectural adornment in Fukien province, and from Fukien spread with Chinese communities to Taiwan and South-east Asia where it is in use to the present day. Itinerant Chinese workmen move from community to community all over South-east Asia, carrying out repairs and building fresh monuments.[205]

Kuangtung province has had a similarly strong influence, both in terms of splendid monuments built within the province itself, and in terms of architectural styles that have been carried to Hong Kong, South-east Asia, Europe and the New World. A famous kiln area that made tiles and related ceramics was Shih-wan 石灣, in the vicinity of Fo-shan 佛山, and Canton, where manufacture continues today.

[204] Yeh Wen-Chheng & Lin Chung-Kan (1993), pp. 166–9.
[205] Legeza (1982), p. 111.

Ceramics were made in the region as early as the Thang dynasty, but it was not until the late Ming dynasty that the production of figures started.[206] At this time during the Ming dynasty, Fo-shan was a very active industrial centre and China's fourth largest city. Small figurines were modelled by hand and larger pieces produced in moulds. The moulds were taken from carved models and could only be used about 30 times. Models were roughly finished on the back, as they were intended to be applied as decoration to halls and temples. Most extant figural tiles and other figurines from Fo-shan and Shih-wan date to the +19th and +20th centuries. They are typified by meticulous, lively modelling, by the use of brilliant, streaky glazes and by the fact that flesh areas were left unglazed. Head, hands and other unglazed body parts were modelled from high-iron clay from Shih-wan mountain, mixed with a small amount of very fine kaolin and Tung-kuan clay 東莞土. The glazed portions were made from a coarser mixture of Tung-kuan clay and sand.[207] Fine models were finished by hand, painted details being added to the hands and face. The influence of the performing arts, especially opera, was strong in the representation of figural styles in Kuangtung.[208]

Tile-making was a specialised trade at Shih-wan and business was kept within the remit of a small number of families.[209] Many pieces were marked with brand names or with the names of individuals or companies. This practice started in the Ming dynasty, to advertise products and to denote quality in a competitive industry. Marks became even more common in the Chhing period, when they also served to differentiate genuine goods from forgeries.[210] From about +1810, a number of Cantonese potters emigrated to Taiwan, where they established businesses that also often employed émigrés from Fukien province. Thus figures and tiles, many of which bear their makers' names, showed a subtle blend of influences from the two southern provinces of Fukien and Kuangtung. Shih-wan ceramic blocks can also be found in Hong Kong, Macau, Bangkok, Malaysia, Jakarta and Vietnam, marking areas of Chinese emigration in the +19th and +20th centuries.[211]

[206] Chuang Chia (1979), pp. 271, 275.
[207] Thao Jen (1979), pp. 285, 291–2.
[208] Fo-shan was a great centre for Cantonese opera, and auditions were held there twice a year at the Hortensia Flower Association Hall 瓊花會館, see Shih Li-Chi (Scollard 1979b), pp. 317, 325.
[209] For some sample lineages of Shih-wan potters, see Shih Li-Chi (Scollard 1979a), pp. 293–307.
[210] See Wu Tseng-Lou (1979), pp. 331–425.
[211] Ho Chui-Mei (1995), pp. 122–3.

HIGH-FIRING LIME GLAZES

THANG DYNASTY HIGH-FIRED WARES

Since they were excavated in such large quantities in the +1920s and +1930s, lead-glazed wares have become the most familiar examples of Thang dynasty ceramics in the world's museums. Nonetheless, in China itself during the Thang period, these spectacular lead-glazed vessels and figurines would have been glimpsed only briefly during funeral parades, and when they were placed on staging outside the tombs, before they were set within in special niches. The populace would have been most familiar with green, white, amber and black-glazed stonewares that served as everyday ceramics for prosperous clients in both north and south China. This might therefore be a good point to return to the subject of Chinese high-fired glazes, which were left at the Han dynasty, with a discussion of the semi-glazed southern stonewares once known as proto-porcelain wares.

DEVELOPMENT OF SOUTHERN STONEWARE GLAZES

After the fashion for sifted or 'sprinkled' techniques, which coincides generally with the Han dynasties, stoneware glaze technology in southern China seems to have returned to the use of liquid glaze suspensions, often applied overall by pouring, dipping and brushing, and most probably to raw unfired wares.

This highly successful technology became the prime method for making south Chinese stoneware glazes, from the +3rd century until the +10th, a period that saw a huge increase in southern stoneware production, with major kiln-complexes arising in most southern provinces. Much of the stoneware made at this time was of the reduction-fired greenware type. This was probably a natural development from traditional southern grey-fired earthenwares, and production of unglazed grey wares, with their natures somewhere between earthenware and stoneware, often continued to be made in parallel with the newer glazed ceramics.

The period from the +3rd to +6th century was an especially vibrant and innovative time for southern greenwares. New and distinctive forms developed: the chicken-headed ewer; the small frog-shaped pot; the burial jar with five spouts or jars on its shoulders;[212] the tiger-shaped urinal; the large burial jar topped with models of people, animals and buildings; and exquisitely made burial miniatures of household effects. Dozens of kilns operated in Chekiang province, among them Hang-chou 杭州, Te-chhing 德清, Phu-hsi 浦西, Wu-hsing 吳興 and Yü-hang 余杭 in the north; Shang-yü 上虞, Shang-lin-hu 上林湖, Shao-hsing 紹興, Ning-po 寧波 and Feng-hua 奉化 in the north-east; Lin-hai 臨海 and Wen-chou 溫州 in the

[212] A punning allusion (*wu kuan* 五官 / 五管) to official advancement.

south-east; and Chhu-chou 處州 and Chin-hua 金華 in the south-west.[213] In Chiangsu province kilns at Chün-shan 均山 and I-hsing 宜興 were dominant,[214] while in Anhui province more than ten kiln centres were active at Shou-chou 壽州 from the +5th century to the Thang dynasty. Shou-chou ware's height of fame was a mention in Lu Yu's 陸羽 *Chha Ching* (Classic of Tea *c.* +761), the author commenting that:

Shou-chou ware is yellow [so it complements] purple-brown (*tzu* 紫) tea.[215]

In Chiangsi province, the Hung-chou 洪州 site yielded an Eastern Chin dynasty sagger sherd that some archaeologists claim to be the earliest sagger in China.[216] Hung-chou was active from the +2nd to the +10th century, and was mentioned in *Chha Ching* in the same context as Shou-chou ware 壽州窯:

Hung-chou ware is light brown (*ho* 褐) [so it complements] black tea.[217]

Another literary mention concerning Chiangsi province kilns was of a potter named Thao Yü 陶玉 who presented imitation jade (i.e. green-glazed ceramics) to court in either +619[218] or +621.[219] Its success led to the establishment of an official bureau at Hsin-phing 新平, east of Ching-te-chen, and the mention of a famous potter there called Huo Chung-Chhu 霍仲初. In *Ching-te-chen Thao Lu* (An Account of Ceramic Production at Ching-te-chen, +1815) the potters Thao 陶 and Huo 霍 are transformed to become two branches of kilns, *Thao yao* 陶窯 and *Huo yao* 霍窯.[220] One can see the difficulties inherent in establishing early potters' identities with any accuracy.

Kilns were also busy in other southern provinces. In Hunan province, Chhang-sha 長沙 ware was made from the +4th century and by the end of the +5th century greenwares from both Chhang-sha and Hsiang-yin 湘陰 were well established. More than twenty tons of sherds and two whole dragon kilns have been excavated at Hsiang-yin. Among the sherds was an Eastern Chin sagger that local archaeologists offer as another contender for China's earliest known sagger.[221]

In Fukien province, pottery with incipient glazes had been produced as early as the −5th century, but it was not until the Western Chin period (+265–419) that glazes, shapes and decorations closely comparable to greenwares from Chekiang province appeared. Kilns in northern Fukien were clearly influenced

[213] Lovell (1967), pp. 1–3. Watson (1991), p. 125.
[214] Lovell (1967), pp. 3–4.
[215] *Chha Ching* ('*Wan*'), p. 9b. Sherds of yellow ware from Shou-chou are illustrated by Hughes-Stanton & Kerr (1980), nos. 306–15.
[216] Chhüan Khuei-Shan (1995), p. 153, fig. 9, pls. 121–44.
[217] *Chha Ching* ('*Wan*'), p. 9b. Mention of Hung-chou ware is reiterated in *Ching-te-chen Thao Lu*, ch. 7, p. 1b.
[218] *Fu-liang Hsien Chih* (1682 edn), ch. 4, p. 39a, and *Jao-chou Fu Chih* (1872 edn), ch. 4, p. 78, both call the presenter of jade simply *Thao-jen* 陶人 (potter). This may be an example of inevitable mistakes in copying and printing repeat-edition texts that can so confuse Chinese historiography.
[219] *Chiangsi Thung Chih* (1880 edn), ch. 93, p. 5b.
[220] Ch. 5, see Feng Hsien-Ming *et al.* (1982), p. 265.
[221] Facts reported and sherds and kiln furniture presented at sherd session during the Research Society for Ancient Ceramics Annual Symposium at Shih-chia-chuang 石家莊, October +1997. Sui dynasty Hsiang-yin sherds are illustrated in Hughes-Stanton & Kerr, nos. 280–3. Watson (1991), pp. 111–12.

from Chekiang, just across the provincial border.[222] Six Dynasties kilns were also productive in both Kuangtung and Szechuan provinces.[223]

This wealth of greenware kilns, described above, seems to have shared very similar approaches to glaze construction, as is evident in the following analyses of a range of southern wares (Table 84).

This collection of later south Chinese stoneware glazes, made in five southern provinces and dating from the +2nd to +10th centuries, has been prefaced by the three glazes of mid Shang dynasty date from Table 63. Although found in the north, those examples are thought to have come from south China, and they were made some 1,600 to 2,300 years before the rest of the group. They show both the antiquity and the remarkable continuity of south Chinese lime glaze construction, with their chemical bases lying in the lower-melting valleys of the silica-alumina-calcia-magnesia system. Nonetheless, small details in the analyses suggest that some changes occurred in the potters' approach to glaze-making since the Shang dynasty, particularly the R_2O alkali ($K_2O + Na_2O$) levels. These are higher than in the later glazes and imply that southern potters may have practised more thorough washing of their wood ashes as the centuries progressed.

When the above glazes are considered as practical recipes, a balance of about three parts of dry siliceous stoneware clay to about two parts of dry well-washed wood ash provides the best fit for most cases.[224] This assumes the use of dry materials, to which water would have been added to make suitable glaze-suspensions. However, the use of wet materials such as clay slips and/or wood–ash+water mixtures are common in many pottery traditions, and may well have been used by potters in southern China. The use of volumetric measure would have supplied different starting-recipes, but could still have represented this same dry material-balance.[225]

When this 3:2 balance is tested today with siliceous clays and calcareous wood ashes the resulting glazes tend to mature at the point at which Orton cone six bends and touches its support.[226] This pyrometric analogy raises a problem about quoted maturing temperatures that is central to any discussion of ceramics, and that is the relationship of *time* to *temperature* in ceramic reactions.

The essence of this issue is that longer firings at lower temperatures may achieve very similar fired results to faster firings at higher temperatures. This means that, to a certain extent, time may be traded for temperature in ceramic reactions. This makes the simple quotation of a firing temperature for a body or glaze, without mentioning how long the kiln took to reach this temperature over its last couple of hours of firing, an incomplete description. This is a central concern when discussing historical ceramics because how fast a kiln was fired in its finishing stages is rarely

[222] Yeh Wen-Chheng (1994), pp. 120–1.
[223] Lovell (1967), p. 4.
[224] Unpublished experiments by one of the authors (NW) at the British Museum's Department of Scientific Research.
[225] The use of liquid measure for preparing glazes is described in *Thien Kung Khai Wu*, ch. 7, p. 4b. Sun & Sun (1966), pp. 144–5.
[226] For a discussion of firing temperatures and cones see note 101 on p. 117.

Table 84 *Analyses of southern stoneware glazes: −3rd to +10th centuries*

Date	Kiln	Province	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Total
Mid Shang dynasty	Yüan-chhu[a] 垣曲		68.0	7.9	1.0	5.4	13.0	1.3	3.1	0.4	-.-	-.-	100.1
Mid Shang dynasty	Erh-li-kang[b] 二離崗		54.6	14.5	1.4	2.6	19.3	2.7	3.5	0.8	0.3	1.8	101.5
Mid Shang dynasty	Erh-li-kang[c]		57.7	14.0	0.7	2.9	15.4	2.5	3.9	0.8	0.3	1.5	99.7
Eastern Han dynasty	Shang-yü[d]	Chekiang	57.9	13.7	0.6	1.7	19.7	2.4	2.05	0.7	0.9	0.9	100.5
Eastern Han dynasty	Shang-yü	Chekiang	58.95	12.75	0.7	2.4	19.6	1.9	2.2	0.8	0.2	0.8	99.9
Three Kingdoms	Shang-yü	Chekiang	60.9	13.8	0.5	2.0	16.9	2.2	1.9	0.8	0.3	0.8	100.1
Thang dynasty	Wen-chou	Chekiang	63.7	11.7	0.6	1.9	15.1	2.7	1.6	0.8	0.4	1.6	100.1
Thang dynasty	Yü-yao	Chekiang	61.3	13.1	0.5	1.5	16.6	1.9	2.6	0.4	0.6	1.0	99.2
Thang dynasty	I-hsing	Chiangsu	62.8	11.7	0.7	2.0	15.5	2.8	1.6	0.8	0.4	1.7	100
Thang dynasty	I-hsing	Chiangsu	59.8	12.6	0.35	2.3	17.5	2.6	1.6	0.9	0.45	1.7	99.6
Thang dynasty	Yü-thang 玉堂	Szechuan	56.9	12.1	0.7	1.9	20.3	3.8	2.0	0.2	0.3	2.3	100.4
Five Dynasties	Ching-te-chen 景德鎮	Chiangsi	62.2	14.8	0.3	2.0	17.2	1.3	1.9	0.3	0.2	0.7	100.3
Northern Sung dynasty		Kuangsi	56.8	14.0	0.8	1.7	20.6	3.0	1.3	0.3	0.1	1.2	99.6
1,185°C Silica-alumina-calcia-magnesia eutectic mixture[e]			63.0	14.0			20.9	2.1					100

[a] Deng Zequn & Li Jiazhi (1992), p. 58, table 2.
[b] Zhang Fukang (1986b), p. 41.
[c] *Ibid.*
[d] Kuo Yen-I *et al.* (1980), p. 237, table 3.
[e] Singer & Singer (1963), p. 221, table 54.

known. Nonetheless, it is not too difficult to establish maturing temperatures for ancient glazes by rebuilding them with modern materials, and then firing them in modern kilns; this often allows cone numbers to be established for particular compositions.

Southern greenware glazes made from clay and ash mixtures are a case in point, for while their maturing temperature may have been near to Orton cone six, their actual finishing temperatures could have ranged from 1,185°C (15°C/hr over the last two hours of firing) to 1,255°C (300°C/hr., again over the two firing-hours). However, eutectic mixtures can take some time to reach equilibrium, as their unfritted constituents interact and fuse. As the separate sections of southern dragon kilns tended to be brought rapidly and successively to their finishing temperatures by side-stoking, fast temperature rises through the crucial last 200°C seems likely for these wares. Bearing all these factors in mind a finishing temperature for much southern ash-glazed wares of about 1,220°C seems a realistic figure.

THE NATURE OF LIME GLAZES

The lime glazes described in Table 84 have both advantages and disadvantages. Prime amongst the former is the ease with which they can be made from materials local to the kilns, i.e. from siliceous clays and ashes. Grinding of glazes, which can be a major operation in pottery workshops, was probably superfluous with these mixtures as both clay and ash suspensions could easily have been refined by levigation. The high clay contents of the glaze recipes prevented their settling in use, and also allowed smooth and easy application to the raw wares. The maturing temperatures for lime glazes occur towards the lower end of the stoneware range, and their eutectic basis makes them tolerant of variations in kiln temperatures. In addition to this, the fired surfaces of lime glazes are much harder than earthenware glazes which, combined with the tough stoneware material beneath, produced an extremely strong product. Lime glazes are also useful for enhancing any carved or impressed decoration in the clays, as lime glazes become transparent with fast cooling, but darken substantially where they pool and thicken in any surface detail. The lightly incised decoration used on many of the finer Yüeh wares 越窯 exploited this phenomenon to good effect.

These many advantages help to explain the long and successful career that lime glazes enjoyed in southern China, acting for more than 2,000 years as a major glaze-type, and providing a technology that was used at thousands of kiln sites across the south. Lime glazes did have some drawbacks, chief of which was a low viscosity at high temperatures, which caused the glazes to run if applied too thickly. In early wares raised parallel ridges controlled this flow, but after the Han dynasties better control of glaze thickness allowed uninterrupted profiles for the wares, and the fired glaze thicknesses, established for the post-Bronze Age wares in Table 84, vary from about 0.1 millimetres to 0.3 millimetres.[227]

[227] Kuo Yen-I *et al.* (1980), p. 234, table 1.

SOURCES OF WOOD ASH

Another potential problem associated with the heavy use of wood ash for glazing south Chinese stoneware may have been the impact that fuel-burning for glaze-ash had on the environment. As mentioned on p. 355 most of the wood ash from the firebox, or from the side-stoking, of a dragon kiln is carried into the kiln-chamber, where it fuses to walls and saggers, or is taken out of the kiln by the draught of the fire.[228] There is also the issue that dragon kilns are rather efficient in their operation, which means that the weight of wood needed to fire them may be only the equivalent of the weight of the setting being fired.[229] As only about 1/250th (0.4%) of the weight of the original fuel would survive as ash, this would fall far short of the ash needed to glaze all the pots in a setting. This assumes that all the wood ash produced in firing could have been recovered, which was far from being the case. Therefore sources additional to kiln-ash must have been used to supply the vast quantities of botanic ash needed for southern stoneware glazes.

For Japanese ceramics, two additional sources of supply have been described, namely household hearths,[230] and textile workers who had already extracted from wood ash the soluble alkali for use in dyeing.[231] It seems unlikely that similar sources could have met the huge demands for wood ash represented by the southern stoneware industries in China, when they were at their productive heights in the +9th to +11th centuries. We can infer that much wood ash at this time was obtained by burning wood, scrub, leaves or stalks, in many cases solely and deliberately for use in glazes.

HOW MUCH WOOD ASH IS PRESENT IN A SOUTH CHINESE STONEWARE BOWL?

It is possible to make some assessment of the proportion of wood ash that is present in the glazes of typical southern stonewares, as numerous data exist for the thicknesses of glazes on Yüeh wares, compared with the thicknesses of their bodies.[232] Typical measurements are 0.25 millimetres for the total glaze thickness (inside and out) and 4.5 millimetres for the body, with glaze-cover on Yüeh ware bowls tending

[228] Père d'Entrecolles, in Du Halde (1737), p. 347.

[229] Data on Chinese, Korean or Japanese dragon kilns, that supply complete information on firing temperature, size of kiln, weight of ware being fired, and weight of fuel used to fire the ware, are hard to find, as there are usually some key aspects of the formula missing. However, a dragon kiln making stoneware plant pots, mostly open-fired, in Singapore in +1995, gave the following figures: length of kiln, 42 metres; finishing temperature, 1,200–1,250°C; length of firing, 36 hours; total cooling, 72 hours; number of pots in kiln, 3,500; weight of wood used in a firing, six tonnes. The average weight of a pot seemed to be about two kilograms and the setting was achieved without using saggers. Pers. comm. at the Sam Mui Kuang Pottery 三美光陶藝 operated by the Chua 蔡 family, Singapore +1995. Another useful source is Terpstra (2001), p. 29, describing a typical Ching-te-chen cross-draught porcelain kiln. This took 25–35 tonnes of wood to fire 10–15 tonnes of porcelain work to 1,300°C+, excluding the weight of the saggers.

[230] Sanders (1967), p. 99.

[231] Cort (1979), appendix B (Shigaraki in +1872), p. 319.

[232] Vandiver & Kingery (1985), pp. 218–19; Kuo Yen-I *et al.* (1980), p. 243, table 1.

to be total. As the specific gravity of a fired stoneware glaze is comparable to that of a fired stoneware body[233] the relative weights of the glaze and the clay that make up a bowl can be calculated from these figures.[234] As some 40% by weight of the glaze will be wood ash, with the remainder clay, the weight of the glaze should be multiplied by 0.4 to supply the original weight of the ash used. Calculations of this type suggest that wood ash represents some 1.5–2.0% of the weight of a typical fired Yüeh ware bowl. So, for example, a small glazed Yüeh ware bowl that weighed 200 grams might have had an ash-content in its glaze of 3.5 grams. At 0.36% ash-yield from burning + washing, the weight of the botanic material needed to supply this ash would have been 277.7 × 3.5 grams, that is some 972 grams.

When the amounts of fuel needed to create wood ash for glazes are considered from this perspective it appears as if, in many cases, the amounts of botanic fuel needed for glaze-making must have far exceeded those used for firing the same wares. This may have had some relevance to the adoption of limestone as an important glaze-flux at south Chinese kilns in the +10 to +11th centuries (see pp. 553–5), and perhaps too had some bearing on the decline of the ash-glazed Yüeh ware tradition in Chekiang province over the same period.

YÜEH WARES 越窯

Yüeh wares were the prime south Chinese lime-glazed ceramics and they were made in large numbers in the late +8th, +9th and +10th centuries, latterly under the patronage of the small states of Wu and Yüeh 吳越国 located in present-day Chekiang province. Members of the Chhien clan 錢氏 were proclaimed princes of Wu and Yüeh at Hang-chou in +907, and ruled until +978.[235] In the early Sung dynasty the Wu-Yüeh sent tribute to the new court at Khai-feng 開封, but in +978 the Chhien surrendered and lots of commemorative pieces were made then with inscriptions *wu yin* 戊寅 and *Thai-phing hsing kuo* 太平興國. Yüeh kilns continued for several decades and in the Southern Sung period were still supplying ritual vessels to court. Some Chhien family tombs contained impressively large pieces, including vessels from the tomb of the mother of the first ruler, dated +901, in which vessels decorated with underglaze-brown were found. Painting seems to have continued until the mid +10th century and was then discontinued.

The highest-quality Yüeh ware ever made was that known as *mi-se* 秘色 ('secret-colour', see p. 272), that bore lustrous, greenish glazes. This type of ware was valued by connoisseurs and written about by poets such as Hsü Yin 徐寅, a diplomat in the Chhien-Ning reign (+894–898) of the Thang dynasty. He composed a poem called

[233] Typically 2.6 g/cm³ for the glaze and 2.5 g/cm³ for the body.

[234] Sundius & Steger (1963), p. 467, note that the True Specific Gravity (i.e. Specific Gravity that disregards porosity) of stonewares ranges from 2.5 to 2.6. Little is published on the S.G. of glazes, but general estimates can be calculated from the glazes' oxide compositions and the specific volumes of these oxides (the 'Additive Theory', see Scholes (1946), pp. 224–6). For a typical Chinese ash-glaze this gives a result of about 2.6.

[235] Bushell (1910), p. 35.

'Tribute Secret-Colour Small Bowls from Yü' about tribute to the imperial Li family 李氏.[236] Yüeh ceramics selected as tribute wares were used in three ways: to fulfil obligation at a local level; to supply inspectors sent from court; and as presentations from administrators and local officials to the court.[237] The ceramics were so valued that they were often bound in precious metals. Many citations to 'tribute secret-colour porcelain' (*kung mi-se tzhu* 貢秘色瓷) from Wu-Yüeh were noted during the Five Dynasties and early Sung period, for example:

In +935, 200 gold-rimmed porcelain *mi-se* vessels were among tribute
In +966, over 10,000 porcelain vessels with gold mouth
In +973, 50 gold-decorated *mi-se* pieces
In +975, 10,000 wares with gold mouth
In +980, 140,000 porcelain tribute wares, that also included some Hsing ware
In +983, 7 silver-rimmed vessels.[238]

In the early Sung period Yüeh kilns supplied mandatory tribute wares to court, alongside Hsing 邢窯, Ting 定窯 and Yao-chou 耀州窯 manufactories in north China. Kilns in the Ning-po area were specially mentioned.[239] One of the chief needs was for ritual vessels, which increasingly were made in ceramic rather than bronze. For example, in +1083 an imperial decree was issued stipulating that ritual vessels be made in ceramic, with strict regulations as to form and style.[240] In +1131 ceramic vessels in traditional bamboo and wooden styles were made in Yüeh-chou for the annual imperial sacrifice at the Hall of Enlightened Rule (*Ming Thang* 明堂).[241] In +1134 sixty vessels in bronze form *tou* 豆 were requisitioned, along with twelve ceramic *fu* 簠, twelve *kuei* 簋, 50 *tsun* 尊 and 50 *lei* 罍, all in a pre-determined temple style. They came from kilns in the Shao-hsing area.[242]

High-quality tribute Yüeh ware did not come from officially established kilns as did later imperial wares from Ching-te-chen (see pp. 185 and 272). Separate official kilns and administrative offices had not yet been established in the Thang dynasty, Five Dynasties and Sung periods to protect imperial exclusivity, though by the +10th century levies of ceramics were systematised by central government. Although many traditional sources emphasise that tribute ware was not made for commoners,[243] in fact many fine-quality Yüeh wares were exported, and have been excavated from sites all over the world (see pp. 716, 730 and 732). Tribute Yüeh ware was

[236] *Chhin Ting Chhüan Thang Shih*, ch. 710, p. 8174.
[237] *Hsin Thang Shu*, *Tshe* 29, ch. 180, pp. 1a–6b.
[238] Thirteen citations were made in *Shih Kuo Chhun Chhiu*, ch. 78, 79, 80, 81, 82, 83. See also *Wu Yüeh Pei Shih*, ch. 4. *Sung Shih*, ch. 480 ('*Shih Chia San*'), p. 1a, and *Sung Hui Yao Kao*, *Tshe* 199, ch. 4258.
[239] *Thai-Phing Huan Yü Chi*, ch. 59, p. 5, ch. 62, p. 4, ch. 96, p. 5. *Sung Shih* ('*Ti Li Chih*'), ch. 85, p. 20, ch. 86, p. 6, ch. 87, p. 4. *Yüan-Feng Chiu Yü Chih*, ch. 2, p. 13, ch. 5, p. 13. *Sung Hui Yao Chi Kao* ('*Shih Huo*'), 41:41, 52:37.
[240] *Ku Chin Thu Shu Chi Chheng*, *Tshe* 716, p. 77.
[241] Hucker (1985), p. 334. Ts'ai Mei-Fen (1996), p. 123.
[242] *Sung Hui Yao Chi Kao* ('li'), p. 24:86.
[243] *Chekiang Thung Chih* (1899 edn), ch. 104 ('*Wu Chan*'), p. 26b. *Shao-hsing Fu Chih* (1792 edn), ch. 18 ('Wu Chan 2'), pp. 34a–35a. Later scholars took a more realistic view, for example Lan Phu 藍浦 wrote that Thang dynasty Yüeh ware was actually the original kiln of *mi-se* ware of the Chhien clan, and only afterwards was called porcelain made for imperial use, its origin having been forgotten. Cf. *Thao Shuo*, ch. 2, pp. 3a–b.

the highest-quality product of several commercial kilns in the area, some managed by clans with many skilled craftsmen that also made everyday products for general sale. Saggers with traces of glaze sealant have been discovered, which suggests well-protected firing of a small number of individual pieces among the kilns' huge output. Some pieces were inscribed with their maker's name, for example, 'skilled craftsperson Wang 巧手王', or 'fired by Hsü Chhing 徐慶記燒', indicating that skilled craftsmen made the wares while a shared syndicate of several clans did joint kiln-firing. From the Southern Sung, Yüeh kilns in the north of Chekiang declined under pressure from Lung-chhüan 龍泉窯. The +1899 local gazetteer for Shang-lin-hu, *Yü-yao Hsien Chih*, recorded its later fate:[244]

> Shang-lin-hu kilns fired secret-colour wares and officials came to the kilns, but now they are in ruins. Today local potters only make rough tiles and pots etc. In the Sung secret-colour ware was made at Yü-yao 餘姚, which although simple has lasted and today is seen as official ware.

Polychrome Lime Glazes

The tendency for southern potters, including those producing Yüeh wares, to make their glazes largely from stoneware clays meant that high levels of titania (for example, 0.4–0.9% TiO_2) were inevitable in southern lime glaze compositions. The practical effect of basing these glazes on stoneware clays was to cause most southern lime glazes to fire grey-green in reduction and amber in oxidation, as titania has a strong yellowing effect on iron-solution colours. Because southern stoneware body-materials are so consistent in their oxide make-ups, additions of wood ashes to these clays produced a remarkable uniformity of glaze composition across southern China, and this makes discrimination of wares from the many thousands of kiln sites that operated in the area, from the +6th to the +10th centuries, a challenging, if not impossible, task.

However, one way for southern kilns to escape this uniformity was to add to traditional greenware glazes colouring oxides over and above those provided naturally by their major glaze constituents, and then to fire the kilns with predominantly oxidising atmospheres. Two kiln-complexes in particular followed this path: those between Thung-kuan 銅官 near Chhang-sha in Hunan province, and those at Chhiung-lai 邛崍, more than 300 miles to the west of Chhang-sha, in Szechuan province.

The Chhiung-lai Kilns

The Chhiung-lai ware commonly seen has a poor quality, brown body that needs to be slipped. Ceramics from kilns in Szechuan province had both onglaze and underglaze decoration. Most were glazed light green, yellow or brown, and bore sketchy

[244] *Yü-yao Hsien Chih* (1899 edn), ch. 6 ('wu chan'), p. 3b.

floral painting usually drawn in brown. Clays in the province were high in iron and titanium oxides and thus were of lower quality than Chhang-sha wares from Hunan province. Three methods were employed to cover the dark body: white slip, opaque glazes and dark-coloured transparent glazes. A few white-bodied wares are known from Chhiung-lai, but even they are not fine.[245]

In spite of their rough quality, the wares were admired by discerning patrons like the great Thang dynasty poet Tu Fu 杜甫, who went to live in Chheng-tu 成都 in +759. He built himself a 'thatched hut' west of the city, and enjoyed a simple life. One of his poems praised bowls from kilns at Pa-hsien 巴縣 (Chhung-chhing 重慶) that were transported to the 'Brocade City' (Chheng-tu). He described them as having a light yet strong body-material that was whiter than snow and resonant like jade:[246]

Wares from the Ta-Pa kilns are both light and strong
Inverted, they chime like jade and are all the rage in the Brocade City
Lovely bowls white as snowy rime in the homes of the gentry
Outshine even eagerly awaited Spring buds

大巴燒瓷輕且堅, 扣如哀玉錦城傳, 君家白碗勝霜雪, 急送芽齋也可憐

This delightful stanza probably embodied a good deal of poetic licence, for none of the Szechuan wares unearthed to date is of this quality. However, a whiteware kiln has not yet been found at Pa-hsien, so perhaps future excavations could yield pleasant surprises.

Szechuan province started producing ceramics in the Eastern Han period, and developed greenwares with stamped and incised decoration from the Southern Dynasties till the Sui dynasty. It was kilns in the west of the province like those at Chheng-tu, Mu-ma-shan 牧馬山, Chin-ma 金馬, Yü-thang 玉堂 etc. that were active in the pre-Thang dynasty period. Kilns at Chhing-lian 青蓮 and Fang-shui 方水 in the north of the province made pots slightly later, while the best-known Szechuan kilns in Chhiung-lai started manufacture in the Southern Dynasties period, had their peak of production in the Thang dynasty and Northern Sung periods, and declined by the end of the Yuan dynasty.

In the Sung dynasty, kilns in Szechuan province improved their manufacture of white, black and green wares, while also making a small number of *chhing pai*-style 青白 wares. Different kilns specialised in particular wares. Chhiung-lai and Yü-thang made greenwares; Kuang-yüan ware 廣元窯 and Tzhu-feng ware from Pheng-hsien 彭縣瓷峰窯 were whitewares that imitated Ting wares; while Hsi-pa ware from Le-shan 樂山西壩窯, Tung-pei ware from Phu-chiang 蒲江東北窯, Thu-shan ware from Chhung-chhing 重慶塗山窯 and Chhing-hsi ware from Pa-hsien 巴縣清溪窯, were all mainly blackwares, some of which bore phase-separated 'hare's fur' and 'partridge spot' glazes.

[245] Vainker (1991), pp. 84–5.
[246] See Feng Hsien-Ming *et al.* (1982), p. 203.



Fig. 143 Chhiung-lai bowl with dark brown body, thick white slip and green designs painted beneath glaze. Thang dynasty

Moulds were in use from the Five Dynasties period, but were very solid and heavy then. In the Sung dynasty design improvements meant that saggers were hollowed out and therefore lighter. Underglaze decoration continued.[247]

THE CHHANG-SHA KILNS 長沙窯

As the Hsiang river 湘江 flows northwards from Chhang-sha 長沙, the chief city of Hunan province, towards the smaller city of Thung-kuan, it passes through an area of major kiln activity. There were three major kiln groups, which can be distinguished as: those nearest to Chhang-sha, south of Shih-chu lake 石渚湖; those around the site of Wa-cha-phing 瓦渣坪; and those around Thung-kuan.[248] Collectively, they are referred to as the Chhang-sha kilns, and they produced a variety of wares. Some were monochrome green and brown, but all three kiln groups also specialised in the manufacture of underglaze-painted pots from the +7th to +10th centuries. Like Szechuan province, however, Hunan province produced ceramics from pre-Thang dynasty times, while kilns elsewhere were active long after the demise of Chhang-sha wares.

[247] Chen Liqiong (1986), pp. 321–4, Chen Liqiong (1992), pp. 564–9.
[248] The sites are listed in detail, with site maps, in Timothy See-Yiu Lam (1990), pp. 32–6.

The first surveys of the area were carried out in +1953, and in +1957 Feng Hsien-Ming 馮先銘 and Li Hui-Ping 李輝柄 conducted two exploratory probes into the kiln area around Wa-cha-phing (a name meaning 'piles of potsherds').[249] Another survey in +1958 was followed by massive flood alleviation works in +1964–5, that damaged many abandoned kilns and revealed others for the first time. In the mid +1970s four years of intensive archaeological work clarified the picture yet further,[250] and sporadic excavation continues to this day.

An important difference between northern and southern glazes containing copper at this time was that the 'white' and green northern glazes were essentially transparent, while the southern versions were often opaque, with a visual character not unlike Near Eastern tin glaze. It is a feature of tin-opacified glazes that they can combine opacity with a smooth surface glossiness, due to the near-colloidal nature of the suspended tin oxide crystals that render the glazes white.[251] However, the levels of tin that occur in Chhang-sha and Chhiung-lai white and green glazes were far too low to create opacity and the effect was caused instead by the low alumina and high phosphorous oxides contents of the Chinese glazes. This compositional distinction becomes apparent when opaque glazes from the Chhang-sha and Chhiung-lai kilns are compared with transparent glazes from the site, and also with typical southern greenware glazes, such as those in Table 84.

Low alumina and high phosphorous levels predisposed the opaque Chhang-sha glazes to an odd physical effect during the early stages of cooling, namely the unmixing of the glaze into two immiscible glasses.[252] This separation caused a milky opacity to develop in the glazes. In fact, the effect is closely analogous to milk, where microscopic globules of fat are suspended in water thereby promoting an emulsion-induced scattering of white light.

Liquid–Liquid Phase Separation

When this emulsion phenomenon occurs in glazes it is often known as 'liquid–liquid phase separation', phases being states of matter, such as solid, liquid or gas. As glasses tend not to crystallise in cooling the two separated liquids that developed when the glazes were molten tend to survive in the fired glazes as minute droplets of one glass within the major glassy matrix. However, this separation occurs on too fine a scale to be seen by optical microscopy, and needs scanning electron microscopy, in the order of 10,000 to 20,000 ×, to be resolved.

The minute spherules of glass that appear in cooling tend to interfere with light by a process known as Rayleigh scattering, giving milky-yellow, milky-white, or

[249] Feng Hsien-Ming (1960), p. 71.
[250] Timothy See-Yiu Lam (1990), p. 34.
[251] For a discussion on the role of tin oxide in earthenware glazes, and opacity in general, see Tite *et al.* (1998), pp. 256–7, also Kingery & Vandiver (1986a), pp. 212–13.
[252] Sun Hongwei *et al.* (1992), pp. 242–3.

strong optical blue colours, in the fired glazes.[253] The glaze-colours that develop depend largely on the size of the droplets formed, and this in turn seems to depend on the firing temperatures used. A blue cast is typical for glazes fired in their upper-maturing range, 'moon-white' colours occur in the middle range, while cream colours are more usual when the glazes have been slightly underfired.[254] This glass separation phenomenon is rarely seen in historical earthenware glazes, but it is of prime importance to Chinese ceramics, particularly with the bluish Chün 鈞 glazes that were manufactured in northern China from late +10th to the +14th centuries.[255]

At Chhang-sha and Chhiung-lai the phenomenon was exploited to create opaque white, cream and green glazes, with the green examples using additions of copper-tin pigments to the opaque white bases. With moderate over-firing, these opaque green glazes could develop tones that verged on turquoise as their optical-blue casts, provided by their glass emulsions, combined with the emerald-green solution-colours from dissolved cupric oxide. A typical use for this type of glaze was in the painting and trailing of turquoise and brown-purple glazes on straw-coloured backgrounds (see Fig. 152 on p. 655). The turquoise glaze was also used at Chhang-sha as a monochrome, perhaps in imitation of Near Eastern turquoise-glazed earthenwares.[256]

Low Titania Glazes

The Chhang-sha and Chhiung-lai potters of the later Thang dynasty made very effective use of colouring oxide additions, as well as liquid–liquid phase-separation effects. But despite these advances their glazes were still of the high-lime, high-titania types universal in southern China at this time. Further progress in Chinese high-fired glazes depended on lowering both titania and calcia levels. In the case of titania this was for the sake of colour, and in the case of calcium oxide, for improved glaze quality and better firing stability. Reductions in titania levels in southern glazes were complicated, however, by the fact that the oxide derived mainly from the glaze's prime ingredient, siliceous stoneware clay, and thus could not readily be

[253] Brill (1965), p. 223, notes that 'In true colloids the diameters of the dispersed particles fall between 1 to 500 millimicrons . . . Light scattered from different particles comes off in different directions and so the general effect is one in which colloidal scattering makes light diffuse. Thus, many colloids have a marked turbidity . . . For all suspended materials light of shorter wavelengths (blue and violet) is scattered much more than light of longer wavelengths (red).'

[254] Chen Xianqiu *et al.* (1989), p. 313, write: 'The average size of droplets in Changsha [Chhang-sha] glazes is 1850Å, 2370Å, 3170Å and 4050Å, much coarser than 1000Å of Jun [Chün] glazes, therefore the glazes show emulsive white colour. When they are fired to higher temperatures, their appearances will be similar to Jun glazes, showing strong blue opalescence and hare's streak.' Note: 1μ (millimicron) = 10nm (nanometres) = 100Å (Angstroms).

[255] 'Droplets in Changsha [Chhang-sha] wares are 190 to 400 nm in size, which are near to the range of wave length of visible light and scatter white light evenly . . . The droplet size of Henan [Honan] Jun [Chün] ware is about 100 nm . . . the violet scattering to blue light makes the glaze beautiful blue opalescence.' Sun Hongwei *et al.* (1992), pp. 242–3.

[256] Turquoise-glazed earthenware vessels of Near Eastern style and composition have been excavated at Yang-chou, Chiangsu province, in Thang dynasty contexts. Some Chhang-sha wares may be copying these colours. See Zhang Fukang (1985d), p. 111, for an abstract. A full description by Zhang appeared in an unpublished poster-paper at the +1985 conference, and some data from this poster-paper are reproduced in Wood (1999), p. 214.

Table 85 *Bodies of Chinese Yüeh wares and Korean Koryŏ dynasty celadons compared*[a]

Bodies	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	Total
Yüeh ware	75.4	17.7	0.9	2.4	0.3	0.6	3.0	0.5	0.03	100.8
Yüeh ware	77.0	15.8	1.0	3.2	0.3	0.6	2.6	1.0	0.03	101.5
Yüeh ware	76.6	16.1	0.9	3.3	0.3	0.6	3.0	0.9	0.02	101.7
Koryŏ celadon (Kangjin +12 C)	74.8	17.3	1.0	2.4	0.3	0.3	3.4	0.7	-.-	100.2
Koryŏ celadon (Kangjin +13 C)	73.5	17.6	1.1	2.3	0.4	0.5	3.5	0.9	-.-	99.8
Koryŏ celadon (Kangjin +11 C)	74.3	18.5	1.0	2.0	0.5	0.4	2.3	0.9	-.-	99.9

[a] Compiled from Koh Choo *et al.* (1993), p. 2, table 1; Kuo Yen-I *et al.* (1980), pp. 235–6, table 2, plus unpublished data from the British Museum *c.* +1994.

removed by refining. The only practical way to lower titania levels (and with them the strong yellowish cast induced by titanium dioxide) was to find some low-titania replacement for the stoneware body-clay as the major ingredient of the glaze recipes.

A good model for what could be achieved by this approach is seen in Korean celadon wares of the +10th to the +14th centuries. Although Korean ceramics were made some 800 kilometres to the north-east of the main Yüeh production sites in northern Chekiang province, Yüeh wares and Korean celadons share virtually the same body-materials.[257] This reflects the strong north-east/south-west bias that operates in the regional geology. The surface rocks of south-eastern China disappear under the East China and Yellow seas, to reappear as the landscape of South Korea some hundreds of kilometres to the north-east.[258] This is due to the north-eastwards displacement of the south China block in this area, some 700 kilometres, by the Than-chheng Lu-chiang wrench fault system 郯城－廬江扭捩斷層系統 (see p. 713).[259] Chemical analysis demonstrates the effect of this process clearly (Table 85).

Neutron Activation Analysis (which deals with trace rather than with major elements) can satisfactorily distinguish between Korean celadon bodies and Yüeh wares from Chekiang province, but even at this level the Korean and the Chinese bodies appear rather similar.[260] Koryŏ dynasty celadons and Chinese Yüeh ware

[257] Wood (1994), p. 47.
[258] *Ibid.*, pp. 48–50.
[259] Xu Jiawei (1993).
[260] Hughes *et al.* (1999), p. 307, write: 'Given the enormous distances separating the clay resources of the Chinese mainland (Yue [Yüeh]) and the Korean peninsula (celadons), it was not surprising that that the raw materials can be distinguished by their trace element patterns. Perhaps it is more surprising that they are not more different.'

Table 86 *Glazes of Chinese Yüeh wares and Korean Koryo dynasty celadons compared*[a]

Glazes	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Total
Yüeh	60.9	12.1	0.7	3.0	16.5	3.0	1.4	0.8	0.4	1.6	100.4
Yüeh	57.9	13.7	0.6	1.7	19.7	2.4	2.0	0.7	0.9	0.9	100.5
Yüeh	57.4	12.5	0.8	1.8	20.3	3.0	1.3	0.9	0.4	1.5	99.9
Koryo (Kangjin +12C)	59.1	13.0	0.3	1.8	19.5	1.4	2.7	0.3	0.6	0.8	99.5
Koryo (Kangjin +13C)	58.1	13.9	0.2	1.4	19.9	1.8	2.9	0.5	0.4	0.9	100
Koryo (Kangjin +11C)	64.5	14.0	0.2	1.6	13.2	1.6	2.7	0.7	0.3	0.9	99.7
Silica-alumina-calcia-magnesia eutectic mixture	63.0	14.0			20.9	2.1					100

[a] Compiled from Koh Choo *et al.* (1993); Guo Yen-I *et al.* (1980), and unpublished data from the British Museum *c.* +1994.

glazes also show broad compositional similarities, with analyses that fall near to the 1,185°C silica-alumina-calcia-magnesia eutectic mixture. However, one vital difference is evident in the glazes' titania levels, which are high in the Yüeh glazes, but much lower in the Korean wares (see Table 86). These low levels of titania in Korean celadons allowed the bluish colours of Fe^{2+}+Fe^{3+} to dominate in the glazes, thereby supplying the fine blue-green colours that were so admired by Chinese connoisseurs of the Northern Sung dynasty. No less a personage than the Chinese envoy to Korea Hsü Ching 徐兢, writing in +1123, described Korean wares in these terms:[261]

> Among tea wares, there are small bowls of deep jade kingfisher green with gold decoration. They stole this idea from Chinese manufactures . . . Among ceramic wine vessels (*tsun* 尊), celadons are referred to by Koreans as being kingfisher green. In recent years they have made (such vessels) with great skill and good colour . . . Among ceramic incense burners, there are those of lion shape, also kingfisher green . . . they are the finest type.

The best explanation for this colour difference seems to be that Korean potters made their glazes mainly from the low-titania material, porcelain stone, rather than from stoneware clay, although they still used wood ashes as their main source of calcia, as the phosphorus contents of the Korean glazes reveal.[262] In their own time Korean celadons were compared favourably with Chinese *mi-se* Yüeh wares 秘色越窯. A few *mi-se* Yüeh wares have a certain 'Korean' cast to their colours, so it is not impossible that porcelain stones were used occasionally for some of the finest Yüeh wares of the Thang dynasty, although the practice, if followed at all, must have been a minor one.[263]

[261] *Hsüan-Ho Feng Shih Kao-li Thu Ching*, ch. 32, p. 3.
[262] Wood (1994), pp. 52–3.
[263] An example of Thang dynasty Yüeh ware, made in a Near Eastern glass-bottle form, and with a bluish glaze, is in the Palace Museum, Peking, and illustrated in Wood (1999), p. 36.

EARLY YAO-CHOU WARES 耀州窯

A more significant Chinese anticipation for the Korean style of blue-green celadon appears in some Yao-chou celadon wares of the early +10th century, particularly at the Huang-pao site where bluish-green celadon glazes of exceptional quality were made in the Five Dynasties period.[264] The superficial similarity of these Five Dynasties Yao-chou glazes to Korean celadons has often been noted, and the Huang-pao glazes pre-date the earliest bluish Korean glazes by many decades. Most Five Dynasties Yao-chou glazes contain between 0.1 and 0.2% TiO_2, compared with an average of about 0.6% TiO_2 in typical Yüeh wares of the same date. As the Yao-chou bodies contain as much (if not more) titania than Yüeh ware bodies, this represents a very different approach to glaze-construction to that current in southern China, and means that the Yao-chou potters made little, if any, use of body clays in their glaze recipes. Yao-chou potters of the early +10th century also used lime-alkali compositions in parallel with the more ancient lime-glaze type.[265] Both aspects of early Yao-chou glaze design (low titania contents and lime-alkali compositions) show the advanced nature of their glazes. They also reflect the rather different ways that high-fired glazes had evolved in northern China, perhaps as a result of developments in northern whiteware production. Yao-chou glazes are discussed in more detail on pp. 586–95, and they are best understood against the background of northern and southern porcelain glazes, and also south Chinese celadon wares; so it is these three major ware-types that are considered next.

[264] Wang Fen *et al.* (1996), pp. 55–62.
[265] *Ibid.*, p. 57, table 2.

NORTHERN HIGH-FIRING STONEWARE AND PORCELAIN GLAZES

NORTHERN HIGH-FIRED GLAZES

The subject of high-temperature glazes in north China is complicated by the dearth of examples from periods earlier than the early +6th century, which suggests that glazed stoneware in north China developed much later than in the south. A long 'nurturing phase' is therefore missing from the history of northern glazes, and it seems probable that northern stoneware glazes appeared fully formed, with their compositions perhaps based to some extent on southern glazing practice.

The preference for whitewares over greenwares in north China, from the +6th until the late +9th centuries, also inhibits direct comparisons between northern with southern ceramics at this time, as true whitewares in south China did not become established until the early +10th century. In the north, by contrast, Thang dynasty greenware glazes seem to have benefited from advances made in whiteware glaze technology during the Sui and Thang periods.

Early northern stonewares (mainly +6th century) bear greenish- or amber-lime glazes applied to light-firing kaolinitic clays. The glazes are high in calcia and show phosphorous levels typical of ash-glazes, while their titania contents suggest some use of stoneware clay in the original glaze-recipes. These glazes tend to run at full temperatures, apparently because they were usually applied too thickly. This effect was countered in many +6th-century northern stonewares by glazing only the upper-halves or two-thirds of the vessels, and also by the use of plain or ornamented horizontal ridges around northern jars and ewers, to check the flowing glazes. Where greenish-lime glazes have pooled in these ridges they often show a milky or bluish cast, from liquid–liquid phase-separation effects.

Early northern glazes seem to have been applied as water-suspensions, rather than as sieved or dusted powders, and the few +6th-century glazes that have been analysed seem similar to traditional southern ash-glazes. However, one problem with the use of high-lime ash-glazes in north China would have been that northern *clays* were considerably more refractory than their southern counterparts. This meant that many northern stoneware bodies from this period were underfired, while the glazes used with them were fully matured. At many kiln sites the development of northern glazes involved an exploration of higher firing glaze compositions, in order to bring the maturation temperatures of bodies and glazes into closer harmony.

Perhaps the best illustration of how northern high-temperature glazes developed appears at the Hsing ware kilns 邢窯 in Nei-chhiu county 內丘縣 in Hopei province. A series of greenwares and whitewares from the +6th to the +10th centuries have

Table 87 *Glaze-body pairs of early Hsing greenwares from the Northern and Sui dynasties*[a]

Dynasty	Kiln	Province	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Total
Northern Dynasties	Nei-chhiu (glaze)	Hopei	56.3	14.8	0.7	1.8	17.5	1.3	2.2	3.2	0.1	1.7	99.6
Northern Dynasties	Nei-chhiu (body)	Hopei	65.8	26.6	1.0	1.5	1.7	0.6	1.8	0.3	0.01	0.06	99.4
Sui	Nei-chhiu (glaze)	Hopei	57.1	15.4	0.5	1.8	16.8	2.0	1.6	3.6	0.1	0.9	99.8
Sui	Nei-chhiu (body)	Hopei	67.5	26.7	1.1	1.5	0.4	0.5	1.9	0.3	0.01	0.1	100.0

[a] Chen Yaocheng *et al.* (1989a), p. 225, table 2.

been studied from this site, beginning with +6th- to +7th-century light-bodied stonewares bearing greenish ash-glazes (Table 87).[266]

Superficially these early northern lime glazes appear much the same as the southern high-lime glazes in Table 84, with their phosphorous oxide contents (0.9–1.7%) suggesting the use of substantial amounts of wood ash in the original glaze recipes. However their body clays are rather too high in alumina and too low in silica to have played the same major roles in the glaze recipes, as apparently practised with contemporary southern stoneware. Thermal contours steepen sharply towards the alumina corner of the calcia-alumina-silica-magnesia system, causing mixtures of aluminous clay with calcareous ashes to be high melting and dry in appearance, largely through silica deficiency. That effect can be countered by replacement of aluminous clay with more siliceous materials. This shifts the glaze compositions towards the eutectic area and helps to develop glazes with more serviceable and fusible natures.

In the Hsing greenware glazes, above-average soda levels are evident in their composition, a feature unknown in contemporary southern glazes. The soda could not have come from body clays, as these are low in soda, while high soda levels are also most unusual in calcareous ashes. These high sodium oxide figures may therefore represent some use in early Hsing ware glazes of a crushed albitic rock, the most usual source of insoluble soda in high-temperature glazes. Siliceous materials of this type would have modified the natural refractoriness of calcareous-ash and aluminous-clay mixtures, and taken the glazes towards a more fusible region. In this respect northern ash-glazes were already showing some advanced and novel features in their compositional make-up, albeit developed from practical necessity.

HSING WHITEWARES AND PORCELAINS

Early Hsing whitewares are also unusual, in that they bear lime glazes like the greenwares, but their very low titania levels show clearly that body clays played little if any part in their glaze recipes (Table 88).

[266] Chen Yaocheng *et al.* (1989a), pp. 221–8.

Table 88 *Glaze-body pairs of Hsing whitewares from the Sui dynasty*[a]

Dynasty	Kiln	Province	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Total
Sui	Lin-chheng 臨城 (glaze)	Hopei	63.0	13.5	0.2	0.8	16.6	3.4	1.3	0.4	0.1	0.7	100.0
Sui	Lin-chheng (body)	Hopei	66.0	27.3	1.1	1.8	0.7	0.5	1.8	-.-	0.01	0.1	99.3
Sui	Nei-chhiu (glaze)	Hopei	64.2	14.2	0.1	0.7	14.6	2.9	1.6	0.8	0.06	0.6	99.8
Sui	Nei-chhiu (body)	Hopei	68.2	25.9	1.0	1.7	0.4	0.5	1.9	0.3	0.01	0.1	100.0

[a] Chen Yaocheng *et al.* (1989a), p. 225, table 3.

The clays used for these early Hsing whiteware glazes were probably low titania secondary kaolins, though some use of refined primary kaolins cannot be ruled out. These purer clays were almost certainly adopted to avoid yellow tones induced by the use of high-titania body clays in the glaze recipes, thereby improving the fired colours of the whitewares. Lime-rich Sui dynasty whiteware glazes matured at temperatures lower than the rather refractory porcelain clays that they covered, and this mismatch probably accounts for the glassy, crazed and somewhat glue-like glazes, on immature chalky bodies, that characterise much northern whiteware of the Sui-Thang transition period. There was also a tendency during this period to use sand as temper in the plastic clays, making Sui dynasty Hsing wares appear rather coarser than their Thang dynasty equivalents.

In the Thang period a very superior porcelain material was made at the Hsing ware kiln sites, with bodies and glazes that differed markedly from those of the Sui dynasty (see pp. 155–7). Thang dynasty Hsing wares represented a substantial development in technology, and their production was associated with a raising of kiln temperatures from about 1,260°C to nearer 1,350°C in some cases. In fact, when the glazes and bodies in Table 89 are compared with those in Tables 87 and 88, we are seeing one of the greatest advances in world ceramic history.

The first major difference from the Sui dynasty whitewares in Table 88, is that the Thang dynasty body-clays are very much purer, as shown by their low iron and titania levels. It is not impossible that clays used previously for slip- or glaze-making in the Sui dynasty were adopted as body-materials in the Thang. Very pure clays were also used in Thang dynasty Hsing glazes, and these could have consisted of high-quality kaolins, an albitic quartz-feldspar rock, fluxed by wood ash and/or dolomite. The total flux levels in these glazes are half those typical of Sui dynasty examples, with the difference supplied by the 'hard' oxides of silica and alumina. This allowed Thang dynasty Hsing glazes to mature at the same temperatures as the very refractory porcelain clays they covered, resulting in an intensely white, hard, tough and integrated material.

Table 89 *Glaze-body pairs of Hsing porcelains from the Thang dynasty*[a]

Dynasty	Kiln	Province	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Total
Thang	Lin-chheng (glaze)	Hopei	69.5	19.5	0.1	0.5	5.4	2.4	0.9	1.3	0.05	0.4	100.1
Thang	Lin-chheng (body)	Hopei	69.9	25.1	0.2	0.6	0.9	1.6	0.9	0.9	0.01	0.1	100.2
Thang	Nei-chhiu (glaze)	Hopei	67.3	19.5	0.1	1.0	6.8	2.9	0.6	1.5	0.06	0.5	100.5
Thang	Nei-chhiu (body)	Hopei	68.0	27.0	0.3	0.6	0.8	1.5	0.9	0.9	0.02	0.1	100.1

[a] Chen Yaocheng *et al.* (1989a), p. 225, table 9.

The fact that the calcia levels in Thang dynasty porcelain glazes average 6% CaO, rather than the 15% CaO in the Sui dynasty whiteware glazes, does not strictly mean that the later porcelain glazes were low in lime. The quantities of flux needed for glazes decrease as the melting-point of silica is approached, so it is the ratio of one flux to another, rather than its absolute quantity in a glaze, that determines glaze-type. True lime-alkali glazes contain about twice as much RO (CaO+MgO) as R_2O (K_2O+Na_2O), while the Hsing glazes contain some four times as much RO as R_2O.

The Thang Hsing glazes are actually of the lime-magnesia style, as about one-third of the glazes' RO proportion is present as magnesium oxide, a material similar to lime in its behaviour, but with some useful technical attributes of its own.

Magnesium Oxide as a Glaze-Flux

Magnesia is a powerful ceramic flux in the higher stoneware and porcelain range, but it does not work effectively below about 1,260°C, where it tends to act more as an anti-flux and a matting agent.[267] Its particular virtues lie in its low expansion coefficient, which gives good anti-craze properties. It also has the capacity to enrich the quality of lime glazes, and make them appear less ordinary. The usual sources of magnesia in glazes are the hydrated magnesium silicate, talc ($3MgO.4SiO_2.H_2O$), and the double carbonate of calcium and magnesium, dolomite ($CaMg(CO_3)_2$). The ratios of calcia to magnesia in Thang dynasty Hsing glazes are close to those found in a typical north Chinese dolomitic rock, which may suggest that this material may have been used in quantities of about 15–20%. However the P_2O_5 figures in the glazes also suggest some use of wood ash, which tends to be a major source of calcia but only a rather minor source of magnesia. In this case the extra magnesia could have been supplied by talc. The true source of magnesia in these glazes is therefore difficult to deduce from the analyses as various combinations of raw materials can be made to fit the published figures.

[267] Wood (1999), p. 153.

TING WARES 定窯

As the production and reputation of Hsing wares waned in the later +10th century their place was taken by Ting wares, made some 160 kilometres to the north of the Hsing kilns, at sites such as Chien-tzhu-tshun 澗磁村 and Yen-shan-tshun 燕山村 in Chhü-yang county 曲陽縣.[268] Ting wares began their history as Thang dynasty porcelains when, like Hsing wares they were often exported to the Near East. The heyday of Ting ware occurred in the Northern Sung and Chin dynasties. Those periods saw not only an enormous expansion in Ting ware production, but also manufacture of finest-quality Ting wares for the imperial household.

The most obvious visual difference between Sung dynasty Ting wares and Thang dynasty Hsing wares lies in the warm tones of the former, compared with the colder character of the latter. This was caused by the use of coal-burning oxidised firings at Ting sites, compared with reduction-firings most commonly practised in wood-burning Hsing ware kilns.

Like the best Hsing glazes before them, Ting glazes contain significant amounts of magnesia. This feature was present in Ting ware glazes as early as the Thang dynasty (Table 90).

Parallels with Hsing ware glazes can also be seen in the Ting glazes' low titania levels, compared with the bodies they cover, and their obviously refractory natures. Extra levels of sophistication are evident in these analyses, most notably in the high-silica contents of the glazes, which reinforced the craze-control afforded by magnesia. Another advanced feature of Ting glazes is their general $RO:R_2O$ ratio, which approaches 2:1. This alkaline-earth to alkali balance supplied a certain richness to Ting ware glazes, despite their relatively thin application.

When attempts are made to interpret original Ting ware glaze recipes we meet problems similar to those with Hsing wares. Dolomite and talc are both candidates as sources of calcia and magnesia, and the glazes must also have contained pure (i.e. low titania) clays, together with some source of fine silica. However, the phosphorous contents found in two of the Ting glazes cannot be ignored. Although at 0.2–0.3% they appear low, they are in glazes where the total flux contents are also low, so their flux-to-phosphorous ratios are still characteristic of wood ash.

A further problem with these particular analyses lies in their high refractoriness. This is a hallmark of northern porcelain, but one wonders whether, in this case, some body-material has dissolved into the glazes during firing, to give analyses that are 'harder' than those originally applied. This in turn may well have been a by-product of the extended high-temperature soaks used at the Ting ware kilns.

The firing temperatures proposed for the wares analysed above vary from 1,320 ± 20°C in the Northern Sung dynasty, to 1,250 ± 20°C in the Chin dynasty,[269] though the provisos concerning rates of temperature-rise over the last two hours of firing, mentioned on pp. 525–7, should also be borne in mind. While the successive

[268] Richards (1986), p. 60.
[269] Data from Li Guozhen & Guo Yanyi (1986), p. 138, table 2.

Table 90 *Glaze-body pairs of Ting porcelains from the Thang dynasty to the Chin dynasty*[a]

Dynasty	Kiln	body/glaze	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Total
Thang	Chien-tzhu-tshun 澗磁村	body	59.8	34.5	0.4	0.7	1.1	0.9	1.2	0.7	0.03	-.-	99.3
		glaze	73.8	17.3	0.1	0.5	2.9	2.1	1.6	1.3	0.04	-.-	99.6
Five Dynasties	Chien-tzhu-tshun	body	61.2	32.9	0.6	0.6	3.4	0.9	1.2	0.1	0.02	-.-	100.9
		glaze	74.6	17.5	0.2	0.5	2.7	2.3	2.0	0.6	0.02	0.2	100.6
Northen Sung	Chien-tzhu-tshun	body	62.0	31.0	0.5	0.9	2.2	1.1	1.0	0.7	0.04	-.-	99.4
		glaze	72.1	17.5	0.2	0.7	3.9	2.3	2.0	0.5	0.03	0.3	99.5
Chin	Chien-tzhu-tshun	body	59.2	32.7	0.7	0.7	0.8	1.1	1.7	0.3	0.01	-.-	97.2
		glaze	71.2	19.7	0.4	0.6	4.4	1.6	1.6	0.3			99.8

[a] Li Guo-Chen & Kuo Yen-I (1983), p. 308, table 1, and Li Guozhen & Guo Yanyi (1986), p. 136, table 1. (The latter paper is a shorter version in English of the original +1983 Chinese publication.) Chang Chin *et al.* (1983), p. 20, table 3.

chambers of southern dragon kilns tended to be finished rapidly, the final temperature-rises in single-chambered northern *man-thou* kilns could be extremely slow. This was due partly to the accelerating heat-losses, associated with the higher kiln-temperatures used in the north, but also to the thicknesses of the northern kilns' main structures, which were necessary to counter the outward thrust from their domes. This substantial kiln-mass absorbed much of the heat intended for firing the wares.

There is also evidence from modern firings in Shansi province that very extended soaking periods at full temperatures were often practised for coal-burning *man-thou* kilns in attempts to even the temperatures within the kilns. This led to the local maxim that potters should be quick in making but slow in setting and firing. This was because slow setting avoided later firing catastrophes through faulty stacking of the saggers and wares. The slow final soak was known as the 'black fire' (*hei-huo* 黑火), as it was used particularly for blackware glazes. Besides ensuring proper glaze maturity these long soaking periods helped to even the finishing temperatures within the kilns, although temperature differences of some 100°C were still common in coal-fired *man-thou* kilns, despite this precaution.[270]

In the case of Ting wares there was an extra slowing factor in firing caused by the density of the kiln setting. This was the result of some ingenious packing arrangements devised by Ting ware potters that allowed stacks of porcelain wares to be fired rim-down on near-porcelain setters, often with only millimetres separating the various stacked bowls or dishes. Once assembled, the stacks of wares and their supporting setters were placed in larger and heavier saggars, which were then built into columns to create a dense and substantial setting within the kiln-chamber (see p. 345). Temperature rises during the last stages of firing may have been as slow as 10°C/hr, making 1,280°C in a Ting ware kiln the equivalent of some 1,340°C in a faster-firing modern example. With such extended firings one would expect a certain amount of body-material to have been dissolved into the glazes.

Feldspathic Hsing Ware Glazes

The Hsing and Ting wares, analysed above, provide a logical and understandable development for two great northern porcelain traditions. There remains one type of northern porcelain material, however, that seriously challenges the neat 'evolutionary models' constructed from these analyses. These are the feldspathic Hsing ware porcelains of Nei-chhiu county, two sherds of which were discovered together with the wares described in Tables 88–90. These two sherds of very white and translucent Hsing porcelain, with feldspathic bodies and feldspathic glazes, were dated by their discoverers to the Sui dynasty, but they have no direct compositional parallels in Chinese ceramics past or present. While other Hsing ware types described in Chen Yaocheng [Chhen Yao-Chheng 陳堯成] *et al.*'s paper can be recognised in related studies, the feldspathic wares found at Nei-chhiu remain in a class by themselves.

[270] Shui Jisheng (1989), pp. 471–5.

Table 91 *Glaze-body pairs of feldspathic Hsing porcelains from the Sui dynasty*[a]

Dynasty & Kiln		SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Total
Sui Nei-chhiu	body	65.8	26.8	0.2	0.3	0.4	0.2	5.2	1.0	0.01	0.06	100.0
(YN6)	glaze	71.0	16.9	0.2	0.4	2.7	0.1	6.4	1.4	0.04	0.3	99.4
Sui Nei-chhiu	body	62.9	26.9	0.2	0.4	0.5	0.3	7.3	1.6	-.-	0.01	100.1
(YN7)	glaze	69.4	13.3	-.-	0.6	8.4	1.3	4.7	1.4	0.1	0.3	99.5

[a] Chen Yaocheng *et al* (1989a), pp. 274–5, tables 2 and 3.

The porcelain bodies of these wares were discussed fully on pp. 135–7, but their analyses are repeated here, together with the glazes they bear, to show the relationships between the two porcelain-types (Table 91).

The glaze on the first example (YN6 in the paper) is the more remarkable as it contains nearly two and half times R_2O as RO. It is therefore a true feldspathic glaze that could only have been made with substantial amounts (50% +) of powdered potash feldspar in *its* original recipe. Perhaps the greatest mystery of this technology is not so much that it could have occurred at all (minor use of pure clays and crushed quartz-feldspar rocks can be reasoned from analyses of more conventional contemporary Hsing wares), but that the undoubted ceramic quality that it supplied was not exploited further at the time. True feldspathic glazes do not reappear in Chinese ceramics until the +19th century,[271] although they were compositional types common in Japanese ceramics from the late +16th century onwards.[272]

The glaze on the second example (NY7) is less radical, but still outstanding for its high purity, caused by its low titania and iron oxide contents. It is a lime-alkali glaze of the classic style that later became the compositional basis for most Yao-chou and Lung-chhüan celadons, and also for +14th-century Ching-te-chen porcelain glazes.

KUNG-HSIEN 鞏縣 GLAZES

Judging from the results presented above, lime-alkali and alkali-lime glazes of high purity were pioneered by Hsing potters in Nei-chhiu county in the late +6th century. The alkali-lime glaze-type (in YN6) does not reappear in China's archaeological record until the +15th century at Ching-te-chen,[273] but lime-alkali glazes did see some use at another early northern whiteware site some 500 kilometres south-west of the Hsing ware kilns, at Kung-hsien 鞏縣 in Honan province. Kung-hsien clays were considerably less pure than those used for Hsing and Ting wares, and the whitewares made at this kiln-complex were of a lower quality, and generally lower-fired, than pots made in Hopei province. Their glazes, however, show the low titania

[271] Vogt (1900), p. 584.
[272] Sanders (1967), p. 195; Faulkner & Impey (1981), p. 28.
[273] Li Jiazhi & Chen Shiping (1989b), p. 348.

Table 92 *Analyses of Kung-hsien clays and glazes, Sui-Thang dynasty*[a]

		SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Total
Kung-hsien (lower alkali)												
Kung-hsien 1	body	67.7	26.8	1.3	0.6	0.4	0.4	2.1	0.5	0.04	-.-	99.8
Kung-hsien 1	glaze	64.65	13.9	0.2	0.8	12.3	1.9	3.0	2.2	-.-	-.-	99.0
Kung-hsien 2	body	63.1	30.3	1.2	1.3	0.5	0.5	2.0	0.5	0.06	-.-	99.5
Kung-hsien 2	glaze	67.7	15.9	0.4	0.9	10.8	1.5	2.4	0.8	-.-	-.-	100.4
Kung-hsien (higher alkali)												
Kung-hsien 4	body	53.4	37.15	0.8	0.6	0.5	0.4	5.0	2.1	0.04	-.-	100.0
Kung-hsien 4	glaze	62.5	17.0	-.-	0.7	10.4	1.1	4.1	2.1	-.-	-.-	97.9
Kung-hsien 5	body	52.7	37.5	0.8	0.7	0.6	0.4	5.1	2.2	0.04	-.-	100.0
Kung-hsien 5	glaze	66.8	14.5	-.-	0.9	9.3	1.1	4.3	1.75	-.-	-.-	98.7

[a] Li Jiazhi *et al.* (1986), pp. 130–1, tables 1 and 2.

levels typical of northern porcelains, and some examples also show application of the lime-alkali principle (Table 92).

On this evidence Kung-hsien whiteware-makers seem to have used both lime glazes and lime-alkali glazes in the Sui-Thang period. The lime-alkali glazes appear on bodies that were themselves unusually high in alkalis. Moreover, the Kung-hsien clays were probably natural illites (see pp. 149–51) and appear less 'artificial' in their construction than the feldspathic Hsing ware bodies, which may have been made from mixtures of pulverised primary materials.

Summary on Northern Porcelain Glazes

To summarise the above issues: as porcelain production developed in north China, the unusual nature of the local sedimentary whiteware clays presented the potters with a range of problems with glaze design. Firstly, northern porcelain clays were relatively high in titania and needed colourless glazes to offset the yellowing or greying effects produced by this oxide. Secondly, these bodies were often extremely high firing and new approaches to glaze construction were necessary to match this refractoriness. Thirdly, the unusually low contractions of northern whiteware clays during the last stages of cooling pre-disposed the glazes to crazing, an effect that was particularly noticeable with the lime-glaze formulations used in the Sui dynasty. The first problem was solved through the use of low-titania raw materials in the glaze recipes, the second by reducing the total flux contents of the glazes substantially, and often through use of the high-temperature glaze-flux magnesia. The third problem, crazing, was again helped by the use of magnesia, which has a very low thermal expansion, while in the case of Ting glazes, high-silica levels also contributed a useful anti-craze effect.

A number of these technical advances in porcelain glaze design were also practised by northern stoneware potters, most obviously at Tzhu-chou kilns 磁州窯 in

Table 93 *Analyses of Ting, Kuan-thai and Pheng-chheng glazes compared*[a]

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO
Ting +11–12th C.[b]									
d1	73.4	15.2	0.03	0.8	3.9	1.8	3.1	0.7	0.04
d2	70.1	15.8	0.08	1.0	5.4	2.8	3.2	0.5	0.06
d3	74.4	15.5	0.00	0.6	3.4	1.8	2.5	0.7	0.03
d4	73.3	15.5	0.00	0.8	4.3	2.1	2.2	0.7	0.04
d5	72.7	14.6	0.00	1.1	4.2	1.9	3.6	0.8	0.05
Kuan-thai +11–14th C.									
g-b1	74.72	14.34	0.15	0.33	2.61	0.94	5.06	0.79	0.02
g-b5	73.88	14.92	0.30	0.50	2.87	0.87	4.43	1.13	0.01
g-c2	72.46	16.55	0.24	0.51	3.28	0.58	4.52	0.80	0.02
g-d2	72.49	16.75	0.31	0.70	3.33	0.64	4.00	0.71	0.02
Pheng-chheng +11–14th C.									
	71.65	14.40	0.32	0.89	4.86	0.32	5.77	0.72	0.02
PS	73.34	16.50	0.25	0.89	1.59	0.32	5.25	0.76	0.02

[a] Leung *et al.* (2000), p. 135, table 3.
[b] The recent analyses of Ting glazes made by Leung *et al.* (2000) show them to be less refractory than the Ting glazes in Table 90, which may contain a certain amount of dissolved body clay in their compositions.

Table 94 *Analyses of Tzhu-chou ware white slips from Kuan-thai and Pheng-chheng kilns, Hopei province, compared with Shang dynasty whitewares from An-yang, Honan province*[a]

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Total
Tzhu-chou slips											
Northern Sung dynasty, Tzhu-chou	54.2	37.3	0.9	1.0	2.7	0.2	1.8	0.8	-.-	-.-	98.9
Chhing dynasty, Tzhu-chou	53.0	36.4	1.4	1.1	1.0	0.3	2.5	0.1	-.-	-.-	95.8
Shang dynasty, whiteware	51.3	40.8	2.2	1.1	1.6	0.5	0.5	0.7	-.-	-.-	98.7
Shang dynasty, whiteware	57.2	35.5	0.9	1.2	0.8	0.5	2.3	1.3	-.-	-.-	99.7
Shang dynasty, whiteware	57.7	35.1	1.0	1.6	0.8	0.6	2.2	1.0	-.-	-.-	100.0

[a] Chen Yaocheng *et al.* (1988), p. 36, table 2; Luo Hongjie (1996), database; Yang Gen *et al.* (1985), p. 30; and Sundius (1959), pp. 108–9.

southern Hopei province, such as Kuan-thai 觀台 and Pheng-chheng 彭城, where low-flux, lime-alkali glazes were applied to the local stoneware clays (Table 93).

The strong parallels that exist between Tzhu-chou glazes and those from the Ting ware kilns suggest that some transfer of experience occurred from north to south Hopei province, probably in the +11th century. However, while Ting glazes tended to be glossy, the Tzhu-chou glazes were more often dull but still transparent,

perhaps due to faster and/or lower firings at the Kuan-thai and Pheng-chheng kilns. Nonetheless the use of slightly underfired porcelain-style glazes on Tzhu-chou wares suited the local technology admirably: glossy and reflective glazes would have detracted from the black-and-white painted slip designs, and from the *sgraffito* ornament, used so successfully on these carved and painted country wares.

White clays used for white slips in southern Hopei province have proved very similar to clays used for the bodies of Shang whitewares. This is understandable, as An-yang is only some 40 kilometres south of the Kuan-thai and Pheng-chheng sites (Table 94).

To some extent Tzhu-chou wares acted as repositories of northern porcelain technology, long after the northern porcelain kilns declined, following the invasions of north China by the Chin tartars in +1127, and by the Mongols in +1219 and +1234. The technical sophistication seen in the finest northern porcelain glazes was rarely matched in southern China. This was in spite of the spectacular success of southern porcelain manufacture that occurred in the centuries following the decline of the northern whiteware kilns. This was due largely to southern porcelain materials' lending themselves to some very simple, versatile and successful compositional principles. Those principles in turn had derived from earlier experiences with stoneware glaze construction.

CHING-TE-CHEN 景德鎮 WHITEWARE AND PORCELAIN GLAZES

The earliest examples of white porcelains at Ching-te-chen so far found are dated to the Five Dynasties period. They occur at kiln sites such Hu-thien 湖田 and Yang-mei-thing 楊梅亭 where they are found in kiln spoil-heaps with grey-green glazed stonewares of a local Yüeh ware style.

Five Dynasties Ching-te-chen whitewares are mainly bowls with thickened rims and handled and spouted ewers.[274] These early porcelains were fired both with and without saggers, and were usually raised from the kiln floors on stout thrown columns. Much of this early southern porcelain is made in the northern whiteware style, which is a reminder that, despite the great antiquity of southern glazed stoneware, the history of south Chinese white porcelain production began some 300 years later than its northern equivalent.

As discussed on pp. 214–16, the overall compositional similarities between Ching-te-chen greenware and whiteware bodies in the early +10th century are deceptive. Vital differences occur in their minor oxides – most notably those of iron and titanium – and these differences explain why the greenware bodies fired dark grey and the porcelains pure white. For a limited period in the early +10th century, greenwares and whitewares saw parallel manufacture in the district, but the quality and the success of the new porcelain material soon established translucent white porcelain as Ching-te-chen's staple production, and caused greenware production to decline.

The early +10th-century Ching-te-chen greenware glaze in Table 95 shows an interesting feature that may be associated with the rise of southern porcelain technology. While its phosphorous content suggests that wood ash was probably its main glaze-flux, in the traditional southern manner, its low titania level may mean that some porcelain stone was used in its recipe. The low titania level may also explain the unusual bluish cast that characterises Ching-te-chen greenware glazes during this period, titania having a decidedly yellowing effect on low-iron glazes in reduction.

Had this been the case it would raise the possibility that porcelain stones may have been used first at Ching-te-chen as partial or total substitutions for body-clays as glaze ingredients, before their adoption there for porcelain bodies. The converse could also be argued, however, namely that the use of low-titania glaze materials spread from porcelain-making to see some use in stoneware glazes.

[274] Examined and photographed by the authors in +1982.



Fig. 144 Sherds of Five Dynasties period white porcelain excavated at Hu-thien



Fig. 145 Sherds of Five Dynasties green-glazed stoneware excavated at Hu-thien

Table 95 *Ching-te-chen bodies and glazes of the Five Dynasties period*[a]

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	P_2O_5	MnO	Total
Five Dynasties greenware body	75.2	16.9	1.2	2.3	0.4	0.6	2.4	0.1	0.05	0.02	99.2
Five Dynasties greenware glaze	62.2	14.8	0.3	1.4	17.2	1.3	1.9	0.3	0.7	0.2	100.3
Five Dynasties whiteware body	77.5	16.9	-.-	0.8	0.8	0.5	2.6	0.35	-.-	-.-	99.5
Five Dynasties whiteware glaze	68.8	15.5	0.04	0.7	10.9	1.2	2.6	0.2	-.-	0.2	100.1

[a] Kuo Yen-I *et al.* (1980), pp. 234–5, tables 2 and 3. Li Jiazhi *et al.* (1986), pp. 130–1, tables 1 and 2, and Research Laboratory for Archaeology and the History of Art, Oxford.

Table 96 *Possible recipe for a Ching-te-chen whiteware glaze*

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	P_2O_5	Total
Actual +10th-century glaze	68.8	15.5	0.04	0.7	10.9	1.2	2.6	0.2	-.-	100.1
82 body:18 limestone	69.0	15.5	-.-	0.8	10.1	0.7	2.4	0.3	-.-	98.8

With regards to the Ching-te-chen whiteware glaze itself, its analysis shows some important and advanced features, particularly the negligible amounts of MnO and P_2O_5 that it contains, which suggest that limestone rather than wood ash was its main glaze-flux. The whiteware glaze is also lower in calcia than the greenware glaze, making it smoother, more unctuous, and more stable, with its lime-alkali nature being similar to some contemporary northern porcelain glazes. These two advanced features (the replacement of wood ash with limestone and a movement away from high-lime formulations) were to become defining features of south Chinese porcelain technology through succeeding centuries.

It is possible to make a case for the whiteware glaze being made from a simple mixture of the body-clay with burned or crushed limestone in about 82:18 body: limestone proportions (Table 96).[275] This assumes the use of a typical Ching-te-chen limestone in the glaze recipe (see p. 555, table 97 for analyses).

While, in one sense, this recipe can be regarded as a continuation of the ancient southern practice of using the body-material as the prime glaze ingredient, the total replacement of wood ash by limestone as the main glaze-flux also represents a major technical advance. Limestone may have been adopted in this case to avoid the slight greyness and the fine misting of bubbles associated with the use of wood ashes in glaze recipes. These flaws seem to be caused by the colouring effects of manganese ions, and by the breakdown of phosphorous pentoxide, respectively. Manganese and phosphorous oxides are far more abundant in wood ashes than in limestones.

Analysis suggests therefore that Five Dynasties Ching-te-chen whiteware body was made from a single material (a kaolinised, quartz-mica rock),[276] while its glaze

[275] Wood (1999), pp. 49, table 13.
[276] See pp. 214–19 of this volume.

was probably the same rock, pulverised and fluxed with limestone. Firing temperatures were modest by northern porcelain standards, in the 1,240–1,260°C range, and the kiln atmospheres appear to have been neutral-to-reducing. Finishing was probably rapid, as was usual with southern dragon kiln-firings. The quality of the ware produced was notably white and translucent, effects that owed much to the low-titania and high-flux natures of the material.

Taken together, these techniques amount to an extremely convenient and straightforward porcelain technology when compared with the high kiln temperatures, prolonged firings, and more complicated glaze recipes proposed for the finest northern porcelains of the same date (see pp. 539–49). As this simple approach to porcelain-making spread through southern China in the +10th century, the enormous potential for southern porcelain manufacture must have become evident.

LIMESTONE AS A CHINESE GLAZE-FLUX

One of the most important and convenient features of this new south Chinese porcelain technology was the use of the cheap and abundant material, limestone (calcium carbonate) as the prime source of calcium oxide, rather than the washed calcareous wood ashes that had sustained southern glaze technology through the preceding centuries.

Pure calcium oxide ('quicklime'), however, was probably not used, as it is a caustic and impractical material that reacts violently with water, liberating considerable heat as it converts to calcium hydroxide (slaked lime). Slaked lime too has some drawbacks as it is slightly caustic, and may even set solid under water through hydraulic effects. Calcium carbonate by contrast is a cheap inert compound that is easy to process, suspends well in water, has slight plasticity, and behaves generally as an ideal glaze constituent. At temperatures higher than about 800°C calcium carbonate breaks down to calcium oxide, with the liberation of considerable carbon dioxide. The calcium oxide thus formed in firing operates as a glaze-flux at kiln-temperatures greater than about 1,170°C.[277]

Apart from wood ash, the main sources of calcium carbonate for potters are chalk, limestone, marble and mollusc shells, both freshwater and marine.[278] All these non-vegetal ash sources are low in phosphates, so very low P_2O_5 levels in a glaze suggest that a glaze's main calcia source be other than ash. The growth of white porcelain in southern China seems to mark a gradual abandonment of wood ash as a major glaze constituent at many kiln sites, in favour of the purer and cheaper material, limestone.

Limestone is an easy material to crush and reduce to powder, particularly in its softer states such as chalk or marble. Crushing and milling are used today for preparing limestone for ceramics in the West. Chalk (known to British potters as

[277] Liu Zheng & Xu Chuixu (1988), pp. 532–5.
[278] See Cardew (1969), pp. 51–3, for a discussion of sources of calcia for ceramics.

whiting) is the usual source of calcium carbonate in the UK, while marble is more popular in continental European factories.[279] In Ching-te-chen, however, a rather different approach to the preparation of limestone was followed. Limestone was burned with wood or bracken and then washed thoroughly to remove traces of ash.

Burned limestone is known to Chinese potters as 'glaze ash' (hui-yu 灰釉), and a surprise to Western and Russian scientists studying Chinese porcelain technology has been that the material proved on analysis to be calcium carbonate ($CaCO_3$), rather than the expected slaked lime ($Ca(OH)_2$). The key to this process seems to lie in the use of two burning temperatures: the first, and higher, temperature with charcoal, the second, lower temperature, with fern. As Georges Vogt explains:[280]

> one concludes that, in the first phase, when one burns limestone with wood charcoal, the temperature should be high enough to make quicklime and in the second, where one only heats with the foliage of ferns, one ought to re-form a large amount of calcium carbonate. Summarising, this operation should only serve to transform hard limestone to a powder that is easy to suspend in water, a condition favourable to the making of a good glaze.

'Recarbonisation' is an effect that can occur during ordinary lime burning, although it tends to be avoided where possible. It happens most often at temperatures near to 650°C and where poor draught causes a local build-up of carbon dioxide.[281] It seems to be these conditions that are deliberately produced in the second burning of 'glaze ash' described by Vogt. The Ching-te-chen material has been analysed by Vogt, by his predecessors at Sèvres, Ebelman and Salvetat, and by the Russian scientist Efremov in +1956 (Table 97).

These analyses are all similar to the limestone rock used at Ching-te-chen for making glaze ash, which suggests that the botanic ash content of the processed material was rather small, as might be expected from the low ash-yield of most plants and trees (typically 0.2 to 1.0%). The prepared glaze-ash was also washed thoroughly after burning and this removed most of the alkali introduced by the fern ash.

How long this burning technique for the preparation of limestone has been practised at Ching-te-chen is difficult to say, but *Thao Chi* suggests that the burning of limestone for glazes was already well established in the area in the Southern Sung dynasty:[282]

[279] For example, Seger (1902d), pp. 729–32, gives numerous porcelain glaze recipes containing ground marble.

[280] Vogt (1900), p. 566: 'on est autorisé à conclure que dans la première phase, l'on chauffe le calcaire avec du charbon de bois, la température atteinte doit suffire pour faire de la chaux vive et dans la seconde où l'on ne chauffe plus qu'avec des feuilles de fougères, on doit reformer une quantité très notable de carbonate de chaux. En résumé, cette opération ne ferait que transformer le calcaire compact en une poudre fine facile à metttre en suspension dans l'eau, condition favorable pour préparer une couverte d'une bonne qualité.' See also Liu Zheng & Xu Chuixu (1988), pp. 532–5, for an accurate account of this process. Liu and Xu also note that: 'treatment with urine leads to the carbonization of the residual calcium hydroxide in the ash.'

[281] Stowell (1963), pp. 13–14, explains: 'the reaction $CaCO_3 \rightleftarrows CaO + CO_2$ should proceed to completion at the requisite temperature. If however the partial pressure of carbon dioxide builds up sufficiently, the reverse reaction takes place, and the rate is at a maximum at temperatures in the neighbourhood of 650°C.'

[282] *Thao Chi*, para 4, as reproduced in Pai Khun (1981), p. 40. This passage is also quoted in Bushell (1896), p. 220.

Table 97 *Analyses of Ching-te-chen 'glaze ash', and limestone from Le-phing 樂平*

Analyst	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	KNaO	Loss	Total
Efremov[a]	6.35	2.3	0.6	49.8	1.36	0.3	38.1	98.8
Georges Vogt[b]	3.9	1.5	0.5	52.4	0.73	0.25	40.9	10.2
Vogt's analysis of Le-phing limestone[c]	1.3	0.6	...	53.7	0.75	trace	42.7	99.1

[a] Efremov (1956), p. 494, table 3.
[b] Vogt (1900), p. 567.
[c] *Ibid.*

Mountain brushwood from the Yu hills 攸山 is gathered to produce ash for glaze manufacture. The method adopted is to heap up lime from the stones in alternate layers with the brushwood mixed with persimmon wood (Diospyros), and to burn them all to ashes. The ashes must be added to 'glaze earth' from Ling-pei 岭背, and then they can be used.

This passage also seems to suggest that a two-stage approach to making 'glaze ash' was followed in the Fu-liang 浮梁 district, presumably to produce fine secondary calcium carbonate ideal for ceramic use. Nonetheless the compositions and firing behaviour of both 'glaze ash' and ordinary powdered limestone would have been much the same, so it is not impossible that some use of powdered limestone pre-dated use of the burned variety at Ching-te-chen, with much the same fired result.

Additional references to the practice show continuity from the Southern Sung dynasty to present times. *Nan Yao Pi Chi* (*c.* +1730–1740), for example, noted the use of calcined limestone using rocks from local hills that were burnt for three days and nights using bracken as a fuel, then crushed finely and quenched with water.[283] Thang Ying's illustration number 3, 'Burning ash and making glazes', likewise confirms that lime for Ching-te-chen glaze came from Le-phing and was made by burning limestone with bracken.[284] More recently, Addis described the process as being repeated seven times and noted:[285]

The fern used for this purpose was growing freely on the Gaoling [Kao-ling 高嶺], and a specimen which I brought back has been identified by the Royal Botanic Gardens at Kew as Dicranopteris linearis (syn. Gleichenia linearis) which is described as a 'wide-ranging old-world thicket-forming plant'.

[283] *Nan Yao Pi Chi*, p. 8b/326.
[284] *Thao Shuo*, ch. 1, p. 3b. See also *Ching-te-chen Thao Lu*, ch. 1, p. 3a.
[285] Addis (1983), p. 63. However, Guo Yanyi (1987), p. 13, differs somewhat on the plants concerned: 'It is clear that even before the Ming in the Southern Song [Sung] period, glaze ash was already made by calcining limestone with wood and leaves. At Jingdezhen [Ching-te-chen] the same method of making glaze ash was used as at Longquan [Lung-chhüan] in Zhejiang [Chekiang]. There were two plants that were used mostly, either 'wolf-chicken' grass (langji cao [lang-chi tshao 狼雞草]) or 'phoenix tail' grass (*Pteris multifada Poir*, a kind of fern) were heaped up with limestone and burned several times; then after it had weathered it was ready.'

CHHING-PAI WARE 青白

As the +10th century progressed, Five Dynasties whitewares, with their noticeably northern influences, were gradually replaced at kilns near to Ching-te-chen by more typically southern products, namely *chhing-pai* or *ying-chhing* 影青 wares.[286] The most obvious feature of this material is its transparent or translucent icy-blue glaze, which sometimes developed a frosty or sugary character in cooling. The cold tones of these reduction-fired glazes often contrasted happily with the faint orange or rusty tones of the reoxidised and unglazed porcelain clays. *Chhing-pai* porcelains tended to be made thinner than Five Dynasties wares, probably partly to increase their similarity to beaten silver, and partly to exploit their good potential for translucency, an effect perhaps enhanced by some interaction between the calcareous glazes and the siliceous porcelains beneath.[287]

Ching-te-chen *chhing-pai* glazes have higher calcium oxide contents levels than the Five Dynasties wares that they replaced, an effect managed by raising the limestone contents of the glazes from about 20% to nearer 30%. This moved their compositions back towards the traditional lime-glaze range, though the very low titania levels in the porcelain materials ensured that the glazes developed watery-blue colours from their natural iron contents, rather than the old Yüeh-type iron-titania grey-greens. Pairs of glaze-body analyses suggest that the porcelain material was the major *chhing-pai* glaze ingredient (Table 98).

With regard to abundance, few wares in China's ceramic history have been copied more frequently and over a broader area than Ching-te-chen *chhing-pai* ware, which was made at least 30 kiln sites at Ching-te-chen alone. As its local name 'the jade of Jao' 饒假玉器 suggests, one stimulus for producing white porcelain with unctuous, pale, green-blue glaze was to imitate jade of the same colour.[288] If so, the mass-manufacture of *chhing-pai* porcelain certainly brought it within the reach of ordinary citizens. *Chhing-pai* was always a popular ware and was not restricted by imperial edict or by production quotas.[289]

Starting in the Sung dynasty other popular-ware kilns in Chiangsi province imitated Ching-te-chen *chhing-pai* ware, and they were followed by kilns in Fukien,

[286] The name *chhing-pai* ('bluey-white') was adopted in the Southern Sung dynasty. The term *ying-chhing* ('shadow blue') was not adopted by connoisseurial writers until the early years of the +20th century, see Feng Hsien-Ming (1987), p. 46. Other homophones and near homophones for the ware include *ying-chhing* 映青, *yin-chhing* 陰青, *yin-chhing* 印青, etc.

[287] Parmelee (1948), p. 152, notes: 'Glazes containing alkalies and calcia, with the latter largely predominating, are more transparent and less viscous, therefore penetrating and reacting more completely with the body. These calcareous glazes should be applied less thickly to avoid the tendency of the fusion to develop a faintly unpleasant greenish colour.' The latter observation is from the standpoint of Western porcelain practice, where fired whiteness is everything. The bluish-green tones of the calcareous *chhing-pai* glazes were, of course, essential to their character.

[288] Feng Hsien-Ming (1987), p. 46.

[289] However, Scott (2001), p. 21, quotes the views of Liu Hsin-Yüan 劉新園 and appears to concur with them, that *chhing-pai* ware might have been made for the imperial court in the Yuan dynasty.

Table 98 *Analyses of Ching-te-chen* chhing-pai *bodies and glazes (Northern Sung dynasty)*

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Total
Bodies											
Ching-te-chen *chhing-pai* 1[a]	76.2	17.6	0.06	0.6	1.4	0.1	2.8	1.0	0.03	-.-	99.8
Ching-te-chen *chhing-pai* 2[b]	75.5	18.4	0.1	0.9	0.6	0.03	2.6	1.2	0.03	0.02	99.4
Ching-te-chen *chhing-pai* 3[c]	74.7	18.4	0.08	0.8	0.6	0.2	2.9	1.0	0.06	0.03	98.8
Glazes											
Ching-te-chen *chhing-pai* 1[d]	66.7	14.3	-.-	1.0	14.9	0.3	2.1	1.2	0.1	-.-	100.6
Ching-te-chen *chhing-pai* 2[e]	66.7	15.2	0.07	1.1	13.9	0.4	1.5	0.6	0.06	0.08	99.6
Ching-te-chen *chhing-pai* 3[f]	65.4	14.0	0.05	1.1	15.4	0.6	2.0	1.0	0.1	-.-	99.7

[a] Chou Jen & Li Chia-Chih (1960a), pp. 89–104 (unpaginated tables 1 and 2).
[b] Luo Hongjie (1996), database.
[c] Li Jiazhi *et al.* (1986b), p. 130, table 1.
[d] Chou Jen & Li Chia-Chih (1960a), pp. 89–104 (from unpaginated tables).
[e] Luo Hongjie (1996), database.
[f] Li Jiazhi *et al.* (1986b), p. 131, table 2.

Kuangtung, Kuangsi, Chekiang, Anhui, Hunan and Hupei provinces. Production flourished in the Southern Sung and continued into the Yuan dynasty. Some *chhing-pai* copies were remarkably fine, for example those made at Jung-hsien 容縣, Pei-liu 北流 and Theng-hsien 藤縣 in Kuangsi province.[290] Other imitations were less successful, such as those from kilns in Hupei. In the Southern Sung period kilns along the south-east coast, particularly in Fukien and Kuangtung provinces, increased production to a marked extent. This manufacturing boom was not promoted by internal consumption, however, for excavation within China has revealed relatively few of these southern wares. The stimulus came from the maritime export trade that operated out of Canton, Chhüan-chou 泉州 and Hsia-men 廈門 (for a discussion of export trade to Asia, see pp. 715–17). Peter Y. K. Lam has synthesised information about Kuangtung kilns of the Northern Sung period, principal among them Hsi-tshun 西村, Chhao-chou 潮州 and Hui-chou 惠州. He points out that their major period of export coincided with Canton's florescence as a maritime port.[291] With a large volume of production through the Sung and Yuan dynasties, Kuangtung *chhing-pai* wares vary, but

[290] For reports on these kilns, see Scott & Kerr (1993), Scott (1995). Glazes in Kuangsi province contained higher levels of manganese that turned them slightly greyish, and more phosphorus that encouraged the production of bubbles and so tended to make the glaze less glassily transparent. Those higher inclusions suggest that Kuangsi province glazes contained significant quantities of plant ash, see Zhang *et al.* (1992).
[291] Peter Y. K. Lam (1985), pp. 1, 9.

typically have a slightly greyish, sugary-textured body and a glaze that stops short of the foot on the outside.[292]

From the +13th century, when Chhüan-chou emerged as a dominant harbour, kilns in Fukien province became more prominent. Thousands of Southern Sung and Yuan dynasty kilns in Fukien province produced vast numbers of ordinary-quality wares. The kilns can be divided into two groups, those in the northern half of the province that were heavily influenced by Ching-te-chen, and those in the southern half of the province, chief among them Te-hua 德化. At Te-hua a Southern Sung kiln of enormous proportions has been excavated at Chhü-tou-kung 屈斗宮 (see p. 358).[293] The huge range of wares does not permit generalisation, but at their best Fukien *chhing-pai* wares had glassy white bodies and rather thin glazes of good blue-grey colour.[294]

To a large extent the success of these various provincial *chhing-pai* kilns depended on the qualities of the local raw materials, and on the potters' access to suitable distribution systems. The purest porcelain stones occurred in southern Fukien province and some of the least pure in Hupei and Hunan provinces. Glaze-fluxes too had some effect on the appearance of these wares. At the Jung-hsien kilns in Kuangsi province, for example, wood ash rather than limestone seems to have been the preferred flux for *chhing-pai* glazes, where it supplied a grey and misty quality to local copies of Ching-te-chen wares.

Glaze Stone

At many provincial *chhing-pai* kilns the porcelain-makers seem to have relied on porcelain body-stones as the bases for their glazes, in the same way as with earlier Ching-te-chen wares. At Ching-te-chen itself, however, there is some evidence that special 'glaze stones' began to be employed for *chhing-pai* glazes as early as the +13th century, as reference from *Thao Chi* (Ceramic Memoir, +13th C) to 'glaze earth from Ling-pei' demonstrates (see p. 555). Analyses of later Ching-te-chen *chhing-pai* wares of the +13th and +14th centuries confirm its continued use (Table 99).

These glazes have sodium oxide contents higher than the porcelain bodies they cover, which disqualifies the body-material as the main glaze ingredient and shows that separate high-albite rocks had been used to make them. Once established, this principle of using specific glaze stones, rather than body-clays, as the bases for glazes, characterised Ching-te-chen porcelain glaze-construction until at least the mid +20th century.

Why this change occurred is not obvious, but it may be related to the exploration of local porcelain-rock resources that led to the +13th- and +14th-century developments

[292] See Hughes-Stanton & Kerr (1980), pp. 39–42, 134–5.

[293] Similar to the dragon kilns at Lung-chhüan, the kiln was 57.10 metres long, 1.40–2.95 metres wide and had seventeen linked chambers. Heat was transmitted up the slope between chambers by means of between five and eight flues that pierced each interior wall. Thang Wen-Chi (1995), pp. 265–6.

[294] For a range of wares see Hughes-Stanton & Kerr (1980), pp. 21–38, 126–33.

Table 99 *Later Ching-te-chen* chhing-pai *ware that uses separate glaze stones in its glaze*[a]

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	Total
Chhing-pai body	75.9	17.2	0.08	0.85	0.55	0.1	2.5	2.45	99.3
Chhing-pai glaze	65.8	13.8	0.06	0.8	14.15	0.6	1.55	2.7	99.5

[a] Chen Xianqin *et al.* (1985b), pp. 16–17 (abstract). Data are taken from their poster-paper.

Table 100 Shu-fu 樞府 *glaze stone compared with San-pao-pheng stone and late +19th-century glaze stones*

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	Total
Average *Shu-fu* glaze stone[a]	76.25	16.9	-.-	0.9	-.-	0.2	3.15	3.4	0.1	100.0
Prepared San-pao-pheng stone (fired)[b]	76.2	15.7	0.02	0.6	0.5	0.3	3.1	3.6	-.-	100.0
Late +19th-century San-pao-pheng stone[c]	74.5	16.0	-.-	(with Al_2O_3)	0.35	0.01	3.2	4.7	-.-	98.8
Yu-kuo imperial factory[d]	78.1	13.1	-.-	0.9	1.1	tr.	2.9	1.2	-.-	97.3
Yu-kuo private factory A	77.8	12.9	-.-	0.65	1.7	0.2	2.9	1.5	-.-	97.7
Yu-kuo private factory B	76.3	13.9	-.-	0.5	1.1	-.-	3.05	1.95	-.-	97.8

[a] Author's (NW's) figures.
[b] Nikulina & Taraeva (1959), p. 457.
[c] Vogt (1900), pp. 543–4.
[d] *Ibid.*, p. 545 (and the next two analyses in table).

in Ching-te-chen porcelain body-materials, described on pp. 232–3. A major feature of this body-change was the use of high-albite, rather than high-sericite, porcelain stones, mixed with some clay-rich material. The good fusibility of these albitic stones seems also to have proved useful in glaze construction.

As described on p. 230, table 41, subtraction of calcia from higher soda Ching-te-chen glazes of the +14th century leaves a material very similar to the high-albite porcelain rock, San-pao-pheng stone 三寶蓬石. San-pao-pheng stone was in use at Ching-te-chen in +1882 as a glaze material when according to Scherzer it was used solely for making crackle glazes.[295] However, by this time (the late +19th century) most glaze-stones used at Ching-te-chen were much lower in albite than San-pao-pheng stone, although still reasonably fusible by reason of their natural calcium carbonate contents. These were known to Ching-te-chen potters as *yu-kuo* 釉果 (Table 100).

Scherzer's report showed that the prepared *yu-kuo* materials also featured in many +1882 Ching-te-chen porcelain body recipes, where they both complemented and supplemented more ordinary porcelain stones. Even so, the *yu-kuo* stones rarely amounted to more than 20% of the Ching-te-chen body recipes, which were made mainly from various types of porcelain stone known as '*pe-tun*' (*pai-tun* 白墩), together

[295] Vogt (1900), p. 543.

Table 101 *Evolution of Ching-te-chen porcelain glazes, +10th to +15th centuries*[a]

Date	Ware type	Glaze type	Typical % 'glaze ash'	Appearance
Early +10th century	whiteware	lime-alkali	20%	Smooth, translucent, white
Late +10th–14th century	*chhing-pai ware*	lime glaze	30%	Icy-blue and transparent
+14th century	*shu-fu* ware	alkali-lime	10%	White, opaque, slightly matt
Mid to late +14th century	underglaze-blue	lime-alkali	15%	Smooth and translucent
Early +15th century	*thien-pai* ware	alkali-lime	0–5%	Very white, slightly translucent

[a] Developed from Chou Jen & Li Chia-Chih (1960a), table 2; Chen Xianqiu *et al.* (1985b), pp. 16–17 (abstract). Data from their poster-paper; Chen Yaocheng *et al.* (1986), p. 124, table 2; and Li Jiazhi & Chen Shiping (1989), p. 349, table 1.

with some 20–30% of kaolin.[296] Vogt notes that *pe-tun* is plastic and moderately fusible, while *yu-kuo* is fusible and moderately plastic, consequently too much *yu-kuo* in a body would have given a porcelain material of low plasticity, together with a tendency to distort and slump at full heat.

Ching-te-chen Porcelain Glazes

The essence of all these technologies is that pulverised quartz-mica rocks, containing varying amounts of kaolin and/or albite, have been the main ingredients of low-iron Ching-te-chen porcelain glazes throughout their 1,000-year history. The most important glaze-flux through this time has been limestone, usually returned to its carbonate state through an ingenious two-stage burning process. The main differences between ordinary Ching-te-chen porcelain glazes during this period lie in their varying stone/limestone proportions, with higher-limestone glazes appearing watery and transparent, while glazes lower in limestone tended to be white and semi-opaque. As the +15th century progressed the fine, smooth and white low-lime glazes were used less often for plain undecorated whitewares, but instead found useful roles as semi-opaque grounds for overglaze enamels.

From the early +10th to the early +15th centuries, the main ware-types produced in the Ching-te-chen district represent a sequence that can be summarised as in Table 101.

Table 101 shows the relative quantities of calcia and alkalis while Table 102 shows their totals within the glazes. This latter table gives a clearer image of their relative fusibilities, with higher flux-totals representing lower maturing temperatures. Some typical analyses from these five stages in early Ching-te-chen glaze design show these varying calcia figures.

[296] *Ibid.*, pp. 553–60. For recent notes on raw materials, see Chang Fu-Khang (2000), pp. 12–14.

Table 102 *Successive Ching-te-chen low-iron glaze types*

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	Total
Five Dynasties whiteware[a]	68.7	15.5	0.04	0.7	10.9	1.2	2.6	0.2	0.2	100.0
Sung dynasty *chhing-pai*[b]	66.7	14.3	-.-	1.0	14.9	0.3	2.1	1.2	0.1	100.6
Yuan dynasty *shu-fu*[c]	73.4	14.6	tr.	0.8	5.3	0.2	2.9	3.3	0.1	100.6
Yuan dynasty blue-and-white[d]	69.5	14.9	0.004	0.8	9.0	0.3	2.7	3.1	0.1	100.4
Yung-Le period *thien-pai* 甜白[e]	72.25	16.0	0.05	0.8	2.65	0.4	5.3	2.0	-.-	99.5

[a] Li Jiazhi *et al.* (1986b), p. 131, table 2.
[b] *Ibid.*
[c] Chen Xianqiu *et al.* (1985b), pp. 16–17, and poster-paper.
[d] Chen Yaozheng *et al.* (1986), p. 124, table 2.
[e] Li Jiazhi & Chen Shiping (1989), p. 349, table 1.

While the original firing temperatures used for these wares depended largely on total flux contents, an extra factor could be introduced by deliberate under- or over-firing. For example, *shu-fu* glazes tended to be marginally underfired and are consequently rather matter than they might be, while *thien-pai* 甜白 ('sweet white') glazes were fully fired, or even slightly over-fired, to give a smooth surface, but still with a slight opacity, despite having lower flux-levels than the *shu-fu* wares. With these provisos in mind, likely finishing temperatures for the ware-types listed in Table 102 may have been:

Five Dynasties whiteware, 1,230–1,250°C
Sung dynasty *chhing-pai*, 1,220–1,250°C
Yuan dynasty *shu-fu*, 1,250–1,280°C
Yuan dynasty blue-and-white, 1,250–1,280°C
Ming dynasty Yung-Le period *thien-pai* 1,290–1,310°C.

These calculations assume typical finishing rates of about 50°C/hr within the kilns.

The useful capacity for different mixtures of glaze-stone and glaze-ash to mature at different temperatures saw its greatest use during Ching-te-chen's later history. From the late Ming dynasty to the mid +20th century, the *chi-tan-hsing yao* 雞蛋形窯 or 'egg-shaped' kiln became the preferred type. The substantial differences in finishing temperatures that operated through the lengths of these kilns – from about 1,320°C at the firebox end to about 1,100°C near the chimney – meant that they could accommodate a wide range of porcelain glaze mixtures.[297] Prepared limestone levels in the glaze recipes used by the potters were adjusted to take this temperature difference into account, and many reports of Ching-te-chen glaze-making describe this practice.

Thang Ying 唐英, for example, noted that the ratio of stone to limestone-ash in the early Chhien-Lung reign period was 10:1 for fine ware, 7/8:2/3 for mid-range

[297] Efremov (1956), p. 492.

wares, and 5:5 for coarse wares.[298] Père d'Entrecolles records porcelain glaze recipes of the Khang-Hsi reign period, where he says:[299]

> For the best that one can make is a mixture of ten parts of oil of stone with one measure of oil made of ashes of chalk and fern. Those who economise never take less than three measures of stone.

The range in this latter case seems to have been from 9% to 25% glaze-ash, though the use of liquid measure makes equivalent real-weight ratios hard to establish exactly, although these may often be deduced from analyses of the fired glazes. The reference to 'economy' in Père d'Entrecolles' letter does not necessarily mean that glaze-stone was a more expensive material in Ching-te-chen than glaze-ash. It probably refers to the greater fusibility of higher glaze-ash mixtures, and their consequent cheapness to fire, as fuel was the prime expense for Ching-te-chen kilns (see p. 213). Any economies achieved with higher-lime glazes, however, were gained at some cost in quality, as these glazes tended to look bluer and less white than the low-calcia versions. Higher-lime glazes were also less viscous at full heat, with a greater tendency for their underglaze-blue pigments to run. For these reasons potters who could afford the rents for the hotter parts of the communal egg-shaped kilns would have preferred to use the stiffer and whiter low-lime glazes.

[298] *Thao Chih Tiu Shuo* incorporated in *Kiangsi Thung Chih* (1880 edn), pp. 19b–23a.
[299] Tichane (1983), p. 63, translation of Père d'Entrecolles' letter of +1712.

HIGH-TEMPERATURE COLOURED PORCELAIN GLAZES: RED, BLUE AND CELADON-GREEN

HIGH-TEMPERATURE COLOURED PORCELAIN GLAZES AT CHING-TE-CHEN

In the +14th and early +15th century a number of coloured porcelain glazes were developed at Ching-te-chen, to be used in parallel with the main production of 'white' glazes. A few of these coloured glazes were used on wares associated with imperial rites, so played key roles in China's state and religious life.

The more important of these single-colour effects were copper-red, cobalt-blue and iron-yellow. The first two were essentially conventional porcelain glazes to which small amounts of colouring oxide had been added, copper and cobalt respectively. As iron oxide gives a rather poor yellow in high-temperature glazes, but a fine yellow in lead glazes, the monochrome yellow was a lead-rich low-firing enamel coloured with about 3% ferric (iron (III)) oxide. This warm, transparent yellow glaze was applied overall to pre-fired porcelain, sometimes glazed and sometimes not. The base-compositions for the two high-temperature glazes were similar to the better qualities of underglaze-blue glaze, i.e. they contained 10–20% glaze ash and were of a lime-alkali type. Glazes with this composition show smoothness, stability and translucency, which are all useful features for displaying single-colour glazes to their best effect.

CHING-TE-CHEN COPPER-RED GLAZES

The copper-red monochrome glaze still stands as one of Ching-te-chen's greatest technical and aesthetic achievements, though it was not strictly a Ching-te-chen invention as the copper-red principle had already been explored at Chhang-sha in the late Thang dynasty (see pp. 653–6)[300] and at Jung-hsien in the Northern Sung dynasty (see p. 657).[301] The colour itself was probably a Mesopotamian glass invention of the mid –2nd millennium.[302] Nonetheless it achieved its greatest quality in ceramic history on fine porcelain ritual wares, made at Ching-te-chen in the early and mid +15th century.[303]

Ching-te-chen monochrome copper-red glazes seem to have arisen from the potters' experience with underglaze copper-red painting. That decorative process probably began in the district in the late +1310s or early +1320s, and perhaps slightly

[300] Zhou Shirong (1985), p. 96, and poster-paper.

[301] For Jung-hsien see Zhang Fukang *et al.* (1992a), p. 379; also Scott & Kerr (1993); Scott (1995). For discussion of early excavated pieces with underglaze copper-red decoration, see Harrison-Hall (2001), p. 66.

[302] Freestone (1987), p. 175.

[303] A series of papers dealing with Chinese copper-red glazes in general, and Ming dynasty *hsien-hung* 鮮紅 'fresh-red' glazes in particular, is published in Scott (1993a).

earlier there than painting with underglaze cobalt-blue (see pp. 658–92).[304] The earliest Ching-te-chen copper-red monochromes so far found have been attributed to the late Yuan period, though such examples have survived only as sherds.[305] Complete vessels of the earliest style of Ching-te-chen copper-red monochrome are most familiar from the Hung-Wu reign period.[306] +14th-century Ching-te-chen copper-reds tend to look somewhat experimental and their colours are liverish or slightly orange, while their glazes often show a waxen character that veils the engraved and moulded-relief designs used beneath the glazes. The pure, glossy cherry-reds, typical of the best Ming dynasty *hsien-hung* 鮮紅 (fresh-red) monochrome production, were not achieved until the early +15th century.

Non-destructive airpath X-ray fluorescence analysis (or EDXRF)[307] suggests that the advances in Ching-te-chen copper-red monochrome technology, evident in the best examples dating to the Yung-Le reign period, were managed through three quite separate improvements in the glaze recipes. First was to make the base-glaze slightly more fusible, i.e. by adding more glaze-ash. This took its composition from the *shu-fu* type towards the underglaze-blue range. The second improvement was to change the copper colourant from the oxidised copper metal, used for copper-red monochrome glazes in the Hung-Wu reign period, to a rather complicated oxidised bronze alloy that contained lead, tin, antimony and arsenic, as well as the usual copper and tin. The third (and perhaps most important) advance was to reduce substantially the quantity of copper used in the glaze to perhaps one-third of its +14th-century level.[308] This combination of a more fusible base-glaze, the in-glaze reducing effects of lead, tin and antimony, and less copper in the recipe, all contributed to the unparalleled qualities of early +15th-century Ching-te-chen copper-reds.

Analysis also suggests that Yung-Le and Hsüan-Te period *hsien-hung* glazes may have used the same type of glaze-stone as imperial quality *thien-pai* 甜白 glazes, that is a rock unusually high in potassium oxide, perhaps from a naturally elevated sericite content. The plain but extremely prestigious Ching-te-chen *thien-pai* wares, excavated from Yung-Le strata in the spoil-heaps of the imperial porcelain factory at Ching-te-chen, can be regarded as 'white monochromes', which suggests that a particular monochrome glaze-stone may have been employed at the imperial factories in the early +15th century. This stone continued in use for Hsüan-Te monochrome copper-reds, which show compositions and qualities equal, and sometimes superior to, the best Yung-Le examples (Table 103).

[304] An early example of underglaze-copper decorated porcelain was found on a Chinese junk that sank off the coast of Korea in +1323. No blue-and-white wares were found on the 'Sinan wreck'. See Munhwa Kongbobu Munhwajae Kwalliguk (1985), pl. 73, no. 94 a and b. Shih Ching-fei (2001), pp. 49–51, discusses the early development of underglaze-brown, red and blue.

[305] Scott (1992), pp. 46–55.

[306] A typical example is shown in Wood (1992a), p. 24, pl. 7. See also Feng Xianming (1985), pp. 44–8.

[307] EDXRF stands for energy dispersive X-ray fluorescence spectroscopy. The 'airpath' version of this analytical technique is non-destructive but is 'blind' to elements lighter than potassium. However, the method can be very sensitive to heavy elements, such as gold and tin.

[308] Wood (1993), pp. 50–2.

Table 103 *+15th-century Ching-te-chen Yung-Le period* thien-pai, *and Yung-Le and Hsüan-Te period* hsien-hung *glazes*

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	CuO	P_2O_5	Total
Yung-Le *Thien-pai* glaze[a]	71.2	15.2	0.1	1.2	2.4	0.6	5.3	2.7	0.1	-.-	0.16	99.0
Yung-Le *Hsien-hung* glaze[b]	70.9	14.0	0.05	1.0	6.4	0.4	4.5	2.6	0.07	0.3	0.1	100.3
Hsüan-Te *Hsien-hung* glaze[c]	69.7	13.9	0.08	0.7	7.7	0.2	4.85	2.4	0.1	0.3	0.08	100.0

[a] Li Jiazhi & Chen Shiping (1989), p. 349, table 1.
[b] Zhang Fukang *et al.* (1993), p. 38, table 1.
[c] Zhang Fukang & Zhang Pusheng (1989), p. 270, table 1.

The Hsüan-Te reign period also saw the production of 'silhouetted' copper-red wares where simple copper-red forms, such as fish or peaches, were produced against a white ground, perhaps with the help of paper-resist or paper stencils.[309] These wares are also rare examples of true 'in glaze' decoration in ceramics, where a second glaze is introduced into a glazed surface before firing.[310] This technique appears to have been difficult, however, and certain legends became attached to its production:[311]

In the Hsüan-Te reign stem cups with a design of red fish were made, the red was derived from Western red precious stone (*hsi hung pao-shih* 西紅寶石, i.e. rubies). The shape of the fish came out from the porcelain during firing and stood out in relief like brilliant jewels.

The belief current in the late Ming dynasty, that powdered rubies (or related red gems, see note 319) were used in some recipes for both monochrome and underglaze Chinese copper-reds, is a curious one. Rubies were accepted as tribute goods from India and Sri Lanka in the early Yung-Le reign period.[312] Among the tribute goods from Sri Lanka in +1433 were rubies and stones called *wan-shih* 碗石 ('bowl stones'), whose exact nature remains unclear.[313] Thailand also supplied rubies and 'bowl stones'.[314] True rubies are large crystals of corundum (aluminium oxide), naturally 'doped' with a trace of chromium. Had they been used in copper-red glazes, their sole effect would have been to make the glazes more viscous in firing, though it

[309] See Wood (1993), p. 26. However Zhang Fukang *et al.* (1995), pp. 191–2, doubt the use of paper-resist or paper stencils at Ching-te-chen at this time: 'In ancient China, paper-cut appliqué practice had been used a lot in Jizhou [Chi-chou] kiln, however it was not used in Jingdezhen [Ching-te-chen] in the Ming and Qing [Chhing] dynasties to make 'fill in red' or 'fill in white' designs.' The reasons for this judgement are not given.

[310] The term 'in glaze' is probably better reserved for a situation where one glaze is introduced to another glaze-surface at the glazing stage. The use of the term 'in glaze' to describe glazes or pigments, whether overglaze or underglaze, that have merged with the main glaze during firing can be confusing.

[311] *Thao Shuo*, ch. 3, p. 2b. *Ching-te-chen Thao Lu*, ch. 5, p. 3b.

[312] *Ying Yai Sheng Lan*, p. 37, *Hsing Chha Sheng Lan*, p. 29.

[313] *Ming Shih*, ch. 326, p. 7. *Ta Ming Hui Tien*, ch. 106, pp. 6–7.

[314] *Ming Shih*, ch. 324, p. 20. *Ta Ming Hui Tien*, ch. 105, pp. 10–11. *Hai Yü*, ch. 1, p. 2.

is hard to imagine a more expensive way of achieving a result easily managed by small additions of clay. Rubies are also some of the hardest materials known, so grinding them to a dust, suitable as a glaze addition, would have been a feat in itself.[315] Although none of these objections proves that rubies were not used in early Chinese copper-red glazes, it seems unlikely that true rubies could have played much part in their success.[316] These reservations may not apply to the rose-red spinel ($MgO \cdot Al_2O_3$), a gemstone that is often confused with true ruby.[317] Spinels are very stable ceramic colours and form the bases of many modern commercial ceramic 'stains'. Nonetheless, while black spinel (Fe_3O_4) has been identified in Sung dynasty Tzhu-chou black slip painting,[318] no red form of spinel colourant has yet been found in early Chinese glazes.[319]

The quality of Ching-te-chen copper-red glazes deteriorated in the +16th century, when the colour was little used. This has been blamed on depletion of the main glaze-stone used for the copper-red colour[320] although the high-sericite glaze-rocks described above do not seem particularly unusual materials. The colour itself is extremely difficult to fire successfully, as the large number of discarded copper-red wares at the kilns at Chu-shan show. While the 1% success-rate reported by Franck for +15th-century *hsien-hung* wares might be pessimistic,[321] good copper-red colours are notoriously elusive, and production difficulties with the glaze may have played some part in its demise. For whatever reason, by the Cheng-Te reign the imperial kilns could no longer produce the glaze. With reference to this time, *Thien Kung Khai Wu* (+1637) relates a variation on the story of the Pottery Deity, whereby a potter killed himself by jumping into a kiln and later appeared in another potter's dream.

[315] Rubies have a hardness (Moh's Scale) of 9 compared with diamond at 10. The scale is logarithmic, but corundum is still a very hard material.

[316] Scherzer reported that *ma-nao* 瑪瑙, pulverised carnelian (a red form of silica), was used in the preparation of a Ching-te-chen underglaze-red pigment at Ching-te-chen in +1882. Vogt (1900), p. 595, doubted that Scherzer's contact had been 'sincère dans sa communication', although the use of carnelian would perhaps have been practical as a grinding aid when preparing the rather soft and flaky copper oxides.

[317] The so-called Black Prince's Ruby, worn by Henry V at the battle of Agincourt, and now conspicuous in the British Imperial State Crown, is really a 'balas-ruby' a rose-red spinel. See Kirkcaldy & Bates (1988), pp. 126–7.

[318] Chen Yaocheng *et al.* (1988), p. 39.

[319] The term 'spinel' refers to the 3:4 ratio of metal (or metals) to oxygen, rather than to a specific individual mineral. Crystals with this atomic arrangement can be 'doped' with other elements (either naturally or artificially) and many examples of spinel provide glass-insoluble and stable ceramic colours. See Singer & Singer (1963), pp. 229–34. However, Wu Lai-hsi (1936), p. 253, suggests that the 'rubies' referred to in the literature may actually have been the 'precious red garnet, which during the Ch'ing [Chhing dynasty] was largely used for adorning the hats and caps of the Manchu princes and nobles. Dr Bushell . . . translated it as the ruby, with which his readers are familiar; but when a Chinese uses term *pao shih hung* he is generally referring to the precious red garnet, the ruby being almost unknown to him.' Garnet is a family name for a group of fairly common minor gemstone minerals that are alumino-silicates of calcium, magnesium, iron, manganese, calcium+iron or calcium+chrome, with a general formula of $RO.Al_2O_3.2SiO_2$ or $RO.R_2O_3.3$ or $5SiO_2$. Garnets have a hardness from 6.5 to 7.5 – that is hard enough for them to be used as abrasives without the super-hardness of corundum (ruby). Kircaldy & Bates (1988), p. 138. Technologically none of these minerals (ruby, carnelian, spinel or garnet) seems a particularly useful addition to copper-red monochrome glazes, but their similarities to copper-red colours may have prompted their use.

[320] *Ching-te-chen Thao Lu*, ch. 5, p. 122.

[321] Franck (1993), p. 87.

Table 104 *+17th- and +18th-century Ching-te-chen copper-red monochrome glazes*[a]

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	CuO	P_2O_5	Total
Wan-Li period copper-red	68.5	13.9	0.04	0.8	10.3	0.2	3.5	2.7	0.05	0.2	0.07	100.3
Khang-Hsi period copper-red	63.3	16.1	0.05	1.2	13.2	0.2	2.6	3.2	0.1	0.6	0.09	100.6
Chhien-Lung period copper-red	63.1	16.4	0.01	1.2	13.4	0.9	2.9	2.2	0.1	0.1	-.-	100.3

[a] Zhang Fukang *et al.* (1993), p. 38.

relating the lost secrets of red glaze. The living potter was thus able to make desired red wares once more.[322] By the second year of Chia-Ching (+1523), kilns at Ching-te-chen were ordered to make porcelain with the 'fresh red' (*hsien-hung*) glaze, but continuing difficulties with the colour meant that the potters had to use the more easily managed 'deep alum red' (*shen fan-hung* 深礬紅, i.e. Fe_2O_3), which was essentially an iron-rich overglaze enamel.

There was a continuing problem with making copper-red monochromes in the +16th century. Several references, for the years +1523, +1530, +1547 and +1571, recommended that the underglaze colour be replaced with overglaze-red which could be more easily produced and was brighter.[323] The pure iron (III) oxide for the low-temperature iron-red was easily obtained from calcined copperas ($FeSO_4$), but there was a clear difference in quality and durability between the two types of red glaze. The Chia-Ching emperor frequently made requests for copper-red glazes, but in vain. In +1547 there was even a reward offered to potters for making 'fresh red'-glazed vessels, but all attempts failed.[324]

Nonetheless, a determined, and largely successful, effort was made to revive the monochrome copper-red glaze at Ching-te-chen in the early Chhing dynasty, when a higher-lime base was used for the glaze (Table 104).

A number of Khang-Hsi and Chhien-Lung period red monochromes exist in the plain and refined style of the early Ming dynasty, and bear Hsüan-Te period marks. These were probably made more as tributes to early wares, and as demonstrations of Ching-te-chen virtuosity, than as outright attempts to deceive. Technically the Chhing dynasty glazes tend to be thinner than the early Ming dynasty examples, and the colours less pure.[325] The colourants too seem different: two examples (from the Khang-Hsi and Chhien-Lung reign periods respectively) have been studied semi-quantitatively by airpath EDXRF, and their colourants shown to have been

[322] *Thien Kung Khai Wu*, ch. 7, p. 8b, Sun & Sun (1966), p. 155.
[323] *Ta Ming Hui Tien*, ch. 201, p. 29b/2717. See also *Chiangsi Sheng Ta Chih* (1597 edn), ch. 7, pp. 45a–47b.
[324] *Chiangsi Sheng Ta Chih* (1597 edn), ch. 7, pp. 26a, 47a.
[325] Zhang Fukang *et al.* (1993), p. 43, fig. 4, found glaze thickness of 0.2–0.6 millimetres for ten Chhing dynasty copper-red glazes tested compared with 0.5–0.9 millimetres for seven early Ming dynasty examples.

pure copper in the Khang-Hsi example and copper with a trace of zinc in the Chhien-Lung glaze.[326] Such colourants would have been less helpful in the complex redox effects that can operate in copper-red glazes than the copper-iron-lead-tin-antimony and copper-iron-lead-tin pigments identified in the glazes of a pair of *hsien-hung* stem-cups of the Yung-Le reign period, and described in the same paper. Nonetheless the iron oxide contents seem deliberately high in both bodies and glazes of Chhing dynasty copper-red monochromes, and iron is thought to be helpful in developing good copper-red colours, in the absence of elements such as tin and antimony.[327]

Whether the higher calcia levels apparent in the Khang-Hsi and Chhien-Lung period copper-red monochrome glazes in Table 104 were Chhing dynasty innovations, or whether the glaze had been moving in this direction for some time is still difficult to determine. Zhang Fukang [Chang Fu-Khang 張福康] and his co-workers present a rare example of a Wan-Li period Ching-te-chen copper-red monochrome glaze (see table 104). This glaze does seem midway between the early Ming dynasty and early Chhing dynasty types. However, data are scarce for this transitional period.

Despite the above reservations, Chhing dynasty copper-red technology at Ching-te-chen was a great advance on later Ming dynasty achievements, and both underglaze and monochrome copper-reds were much improved during this time, famously under the auspices of Lang Thing-Chi 郎廷極 (Superintendent of the Imperial Factory +1705–12).[328] During the Yung-Cheng and Chhien-Lung reign periods official kilns were instructed to copy the finest effects originally achieved in the early Ming dynasty period. For example, in +1729 an imperial request was sent to make imitation Chheng-Hua red dragon bowls. In the eighth month of that year, five red plate sherds were presented to Nien Hsi-Yao 年希堯 to demonstrate their thickness, and to question the reason why new pieces were of contrasting thinness. Nien was ordered to make wares similar to the sherds. In the second month of +1732 there was an imperial request for red, green, yellow and white stem bowls, including thick ones for presentation to the Prince of Mongolia. In +1738, complaints from court (see p. 35) included a request to try to make better coloured red, dragon-decorated, *mei-phing* 梅瓶 vases. In +1739 Thang Ying was on a visit to the capital, where he received a direct court request for vases with copper-red (*yu-li hung* 釉里紅) glazes.[329]

The early Chhing dynasty era also saw the introduction of a new copper-red type at Ching-te-chen, now known in the West as the 'peach-bloom' glaze. This was applied to a range of small and meticulously finished objects for 'the scholar's table' with some nine characteristic shapes comprising the full set.[330]

[326] Wood (1993), pp. 54–6.
[327] *Ibid.*, p. 56.
[328] *Tsai Yüan Tsa Chih*, ch. 4, p. 17, *Chha Yü Kho Hua*, ch. 10, p. 1.
[329] Fu Chen-Lun & Chen Li (1982), pp. 21–2, 55–6.
[330] Cf. Chait (1957) for a discussion of these wares, and Beurdeley & Beurdeley (1974), p. 245, fig. 161, for drawings of eight of the typical shapes. Ayers (2001) goes on to add an important ninth form to the set.

The peach-bloom glaze appears to have been made by sandwiching a layer of sprayed copper-lime pigment between two clear porcelain glazes, a technique that gave a pleasantly varied result that ranged from a warm freckled copper-red to a hazy pink-grey, and even occasionally to an apple green.[331] This attractive glaze was known variously in China as 'beauty's blush' (*mei-jen tshui* 美人翠), 'bean-green' (*tou chhing* 豆青 or *tou lü* 豆綠) and 'apple-red' (*phing-kuo hung* 蘋果紅) glaze. By the early +20th century, Ching-te-chen 'peach-bloom' wares were commanding very high prices and eagerly sought by foreign collectors, particularly Americans.[332] *Thao Ya* (+1910) recorded that:[333]

Small vases with apple-red glaze obtained a price of 5,000 US$ at the St Louis exhibition in America, and now they fetch twice that . . . Although westerners have a deep respect for our antique porcelain we Chinese turn up our noses at the idea of sending it for exhibition.

This was partly defensive on the author's part. In his +1906 preface to the book he complained wistfully:[334]

In recent times our Chinese porcelain industry has fallen into a decline . . . People of China cannot make their country formidable by means of strong ships and long-range guns, nor can they compete in the world market with their labour and materials.

The last development of the Ching-te-chen copper-red occurred when its potters were commissioned by Peking to copy Sung dynasty Chün wares 鈞窯 from Honan province. To these ends various high-temperature glazes were modified with lead and coloured with copper compounds. The results included some spectacular fluid, streaky glazes, shot through with both red and blue.[335] This effect, called *flambé* in the West and *yao-pien* 窯變 in Chinese, is actually caused by phase-separation in the glazes but, before these effects were produced intentionally, there was much fearful speculation about the phenomenon. For example, in the period +1107–10 when abnormal phenomena were observed in the heavens, many examples of *yao-pien* glazes occurred 'coloured red like vermilion sand' (*se hung ju chu-sha* 色紅如朱砂). Kiln workers destroyed most of these pieces. Although *yao-pien* ware was seen as being unlucky in early times, later on it was treasured by collectors.[336]

Further experiments with the *yao-pien* approach at Ching-te-chen resulted in unusually rich and fluid copper-red monochromes that came to be known locally as 'Chün-reds'.

Tests on a limited range of porcelains of +18th-century date using airpath EDXRF, revealed a startling range of solutions employed to reproduce Sung

[331] Wood (1993), pp. 28–9.
[332] Cf. Kerr (1991).
[333] *Thao Ya*, ch. 1, pp. 9a–b. Sayer (1959), pp. 18–19.
[334] *Thao Ya* '*Yüan Hsü*', p. 1a. Sayer (1959), p. 3.
[335] See Kerr (1993), pp. 150–64.
[336] *Chhing-po Tsa Chih*, ch. 5, p. 9.

dynasty Chün wares. Unlike Sung dynasty wares, glazes of different compositions were used on different sections of vessels, many containing lead. This intensely experimental phase was unusual in the history of Chinese glaze technology, and indicated a research-led approach that was probably initially stimulated by imperial demands.[337] Chhing dynasty palace imperial workshop records indicate that the first Chün copies were made in the seventh year of the Yung-Cheng reign period (+1729).[338] Firing of brilliant red-streaked glazes spread from the imperial kiln, so that by the Chhien-Lung reign period 'Chün red' wares were made at many privately owned 'popular' kilns in Ching-te-chen. *Ching-te-chen Thao Lu* (+1815) discusses reproduction Chün ware, using a familiar convention to describe their visual appearance and to rank colours:[339]

> The glaze is multi-coloured and has 'hare's fur' markings 兎絲紋. The best is red like cosmetic rouge, then comes blue-green like spring onions or kingfisher feathers and purplish like ink black. Among the third class plain, unmixed colour ware is best, while pieces with one or two numbers on the base (i.e. copying the size marks on the base of original Chün ware) are acceptable. Examples with blue-green and black mixed together like saliva are all in fact 'three colour pieces' incompletely fired, and are not in a separate class of their own. Slang names are 'prunus blue-green *mei-tzu chhing* 梅子青', 'aubergine skin purple *chhieh-phi tzu* 茄皮紫', 'sea-pear red *hai-thang hung* 海棠紅', 'pig's liver *chu kan* 豬肝', camel's lungs *lo fei* 騾肺', 'nose mucus *pi-thi* 鼻涕', 'sky blue *thien-lan* 天藍', etc. . . . The reproductions of Chün ware made in the town today have an excellent body and the vases and wine jars are mostly very beautiful indeed.

These lead-containing copper-reds continue production at Ching-te-chen today, where as late as +1982 they were fired in one of the last wood-burning, egg-shaped kilns operating within the town.[340]

Ching-te-chen Monochrome Blue Glazes

In the same way that underglaze-red painting seems to have anticipated monochrome red production at Ching-te-chen, a glossy, dark, navy-blue monochrome porcelain glaze appeared at Ching-te-chen during the Yuan dynasty, soon after the introduction there of painting with underglaze cobalt-blue pigments. This fine Yuan dynasty monochrome glaze was often used in combination with unglazed relief ornament (usually three-toed dragons), intended for later gilding, while on some examples the relief ornament was glazed white. Scott suggests that the effect may have been managed by using a cobalt-blue glaze overall, but with a fine sprig of a dragon in white porcelain clay lain on top. The whole was then covered with

[337] See Kerr (1993).
[338] Feng Hsien-Ming *et al.* (1982), p. 20.
[339] *Ching-te-chen Thao Lu*, ch. 6, p. 4a. Saver (1951), p. 53.
[340] Yang Wenxian & Wang Yuxi (1986), p. 206, table 2. The authors visited the factory, with its wood-fired kiln in this year.

a thin clear porcelain glaze and fired.[341] This proposal can be related to a similar technique suggested for some +14th-century Lung-chhüan celadon dishes.[342] On other examples the blue glaze tends to be used alone, without clear overglazes or slips, but sometimes with gilded ornament.[343] Despite the quality of these pieces the very successful rich blue effects seem neither to have been developed nor improved in the later +14th century.

Some rare cobalt-blue porcelain glazes are known from the Hung-Wu reign period, but they show a thin and washed-out quality and are used mainly with high-temperature iron-browns or with copper-red glazes. In this style of ware one colour was used inside and the other out, perhaps in imitation of contemporary two-colour lacquer vessels.[344]

Yung-Le period monochrome blue wares are so far missing from the archaeological record, though this does not mean they were never produced. However, in the Hsüan-Te reign period the character of monochrome-blue glazes from the preceding Yuan dynasty was revived with some success, in the form of glossy navy-blue monochromes.[345] Some Hsüan-Te period blue monochrome porcelain glazes were of imperial quality and sherds of the material show that their blue glazes were often applied in four or five layers to achieve a suitable thickness.[346] A few low-temperature Hsüan-Te period monochrome blue glazes have also survived, some with curiously textured surfaces that bring to mind the copper-containing 'robin's egg blue' glazes of the later Chhing dynasty.[347] A subjective impression is that these low-temperature blue glazes were fluxed with lead oxide, but the mechanisms for their unusual textures are presently unknown, although 'stippling' the glaze on with a stiff short brush, and using a stiff oily medium, may be a possible technique.[348] In the Chia-Ching reign period both low- and high-temperature monochrome cobalt-blue glazed wares were made, some of exceptional size, and the low-fired version also appears as an overglaze

[341] Scott (1989), p. 53. Applying clay on top of a glaze may seem a difficult feat, but the close compositional similarities between porcelain and celadon glazes, and the bodies beneath, make this a practical proposition. Scott writes in description of an example in the Percival David Foundation collection (PDF A362), another example of which is in the Palace Museum collection in Peking.

[342] Medley (1979), p. 11 and p. 19, plate 4b, describes this method, which she calls 'floated relief' as being used on a large +14th-century Lung-chhüan celadon dish in the Percival David Foundation collection London (PDF 255, diameter 43 centimetres), though in this case no clear glaze was used overall. This celadon dish, too, is decorated with a three-toed dragon.

[343] A small blue-glazed porcelain *chüeh* 爵 with traces of gilding, excavated in Anhui province in +1982, nine centimetres high and dating to the Yuan dynasty, and a blue bowl with gilding, eight centimetres in diameter, excavated in Pao-ting 保定 in Hopei province and dating to the Yuan dynasty, are both illustrated in Wang Chhing-Cheng (2000), pls. 243, 244 and pp. 265–6.

[344] See Rogers (1992), pp. 72–3, for a discussion of this unusual porcelain type.

[345] Two from the former imperial collections are illustrated in a catalogue from the National Palace Museum, Taipei. See Liu Pao-Hsiu (1998), no. 166, pp. 386–7, for a dish with white interior, and no. 167, pp. 388–9, for a dish with glossy blue glaze both inside and out.

[346] Results reported by Christine Lau (1994).

[347] For example, a Hsüan-Te period example is in the Capital Museum, Peking. See Anon. (1991b), p. 118, plate 104.

[348] A technique observed by one of the authors (NW) at the Sèvres National Factory in +1992.

Table 105 *+1882 Ching-te-chen monochrome blue porcelain glaze*[a]

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	CoO	loss	Total
+1882 monochrome blue glaze	63.7	13.0	-.-	0.9	6.5	trace	2.9	2.3	1.8	0.4	8.0	99.5

[a] Vogt (1900), p. 575.

enamel.[349] Occasional cobalt-blue monochrome wares, mainly in their high-temperature forms, saw production at Ching-te-chen through the Chhing dynasty, and one late +19th-century example was analysed by Vogt for his +1900 paper (Table 105).

Scherzer's notes show that this was essentially a 77.5:12.5 glaze-stone:glaze-ash mix, coloured blue with an addition of 8 parts of a low-grade (manganese rich) Chinese cobalt. Georges Vogt assessed its firing temperature as about 1,280 to 1,300°C.[350]

Chhing dynasty cobalt-blue effects also included an interesting high-temperature version, applied by spraying a cobalt pigment on to a clear glaze to give an attractive soufflé quality. This can be regarded as a technological relation to the Chhing dynasty 'peach-bloom' glaze, although the 'blown-blue' glaze was not applied to such specialised forms.

Ming Dynasty Imitation of Sung and Yuan Dynasty Glazes

In the Ming dynasty, porcelains with white, red, yellow and blue glazes were specifically chosen by the court as ceremonial vessels.[351] These were specialised ritual wares, but potters at the imperial kilns in the +15th century, particularly in the Hsüan-Te and Chheng-Hua reign periods, also made imitations of classic Sung and Yuan dynasty glazes, such as Lung-chhüan celadons, and the crackle glazes of the Kuan and Ko types. These +15th-century celadon monochromes show the smooth and refined characters of Ching-te-chen prestige porcelains, but are interesting for

[349] Two examples of wares using Chia-Ching cobalt-blue monochrome glazes (one high and one low temperature) are in the Asian Art Museum of San Francisco. See Li He (1996), pp. 242–243 and p. 261. Li writes (p. 261): 'The beautiful blue glaze of the Jiajing [Chia-Ching] period attracted the attention of court decorators, who commissioned a variety of wares, including dishes, bowls, tripods, teapots and jars in this colour.' A small Chia-Ching porcelain dish with a good overglaze cobalt-blue enamel is presently in the British Museum, London, illustrated in Harrison-Hall (2001), p. 251. It has been suggested that the successful use of the overglaze cobalt-blue enamel during the Chia-Ching period was due to the relative purity of the Chia-Ching cobalt pigment – lead glazes being particularly sensitive to excessive impurities (mainly Fe and Mn) in prepared cobalt ores. See Wood (1999), pp. 236–8.

[350] *Ibid.*

[351] Christine Lau (1993), p. 99, writes: 'there were strict regulations regarding the choice of colour . . . Blue was used in the Altar of Heaven, yellow in the Altar of Earth, red in the Altar of the Sun and white in the Altar of the Moon and at the tombs of Ming dynasty royal ancestors.'

Table 106 *+15th century Ching-te-chen copies of classic glazes from Chekiang province*

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Total
Chheng-Hua period Kuan ware copy (glaze)[a]	71.3	14.25	-.-	1.0	3.8	0.2	5.5	3.0	-.-	-.-	99.1
Chheng-Hua period Kuan ware copy (body)	72.9	19.3	0.5	2.3	0.05	0.2	2.7	1.8	-.-	0.07	99.8
Hsüan-Te period Lung-chhüan celadon (glaze)[b]	69.3	14.4	-.-	1.3	7.5	1.1	3.9	1.9	-.-	-.-	99.4
Hsüan-Te period Lung-chhüan celadon (body)	71.9	20.8	0.2	1.2	0.8	0.3	2.9	1.7	-.	-.-	99.8

[a] Chen Xianqiu *et al.* (1986b), p. 164, table 3.
[b] Li Guozhen *et al.* (1989), p. 341, tables 1 and 2.

the evidence that they provide for active connoisseurship and antiquarianism. Once attempted, and achieved, this principle of reinterpreting Sung dynasty and Yuan dynasty classic wares became an established feature of Ching-te-chen porcelain manufacture through succeeding centuries, with the 'five famous wares' (Ting, Ju, Chün, Kuan and Ko) later serving as the main models. Refined reinterpretations of the best Lung-chhüan celadon types are also part of this sophisticated monochrome tradition (Table 106).

The Chheng-Hua period copy of Kuan ware is very much in the style of early +15th Ching-te-chen imperial monochromes, and shows a composition near to the Yung-Le *thien-pai* glaze (see Table 103). Ching-te-chen Kuan ware may well have used the same type of 'monochrome' porcelain stone as the *thien-pai* and *hsien-hung* wares, with the high alkali contents of the rocks inducing crazing in the last stages of cooling. Although superficially similar to Southern Sung dynasty Kuan wares when fired, the use of these high-alkali glaze-stones meant that Ching-te-chen Kuan glazes had rather different compositional bases than the originals from Chekiang province. The earlier glazes were of the high-alumina, low-alkali, lime-glaze type, and their celebrated crackle was induced by low silica levels in both body and glaze, rather than by an excess of glaze-alkali. The body of the Chheng-Hua Kuan imitation, described above, seems to have been a porcelain mixed with refined local stoneware clay, and this ferruginous material supplied the 'purple-mouth and iron-foot' effects, celebrated in genuine Kuan and Ko examples.

Hsüan-Te period copies of Lung-chhüan celadon, by contrast, appear to have been simple lime-alkali porcelain glazes containing extra iron, but applied to a material similar to an ordinary porcelain body. In this case, the colour derived from additional iron oxide in the glaze. By the Chhing dynasty, however, more iron-rich porcelain- and glaze-stones were being used in both bodies and glazes to produce 'counterfeit' Lung-chhüan wares, as Père d'Entrecolles records:[352]

[352] Tichane (1983), p. 104, translation of Père d'Entrecolles' letter of +1712.

The material of these . . . counterfeit antiques, is a yellowish clay which is mined from a place near Ching-te-chen called saddleback hill . . . There is nothing in particular to the making of this kind of porcelain, except that one gives them a glaze made of yellow stone that one mixes with ordinary glaze, so that the latter is in excess.

Georges Vogt also found some use of ferruginous clay (a siliceous ochre) in Ching-te-chen celadons in Scherzer's +1882 samples. Vogt calculated that the late +19th-century Ching-te-chen celadon glaze was made from 71.4% *yu-kuo* 釉果 stone, 15% ferruginous clay and 13.6% glaze-ash. He copied this glaze successfully with French materials at Sèvres in the late +19th century, using a recipe of red clay 12%, quartz 32%, china clay 12%, feldspar 30% and limestone 14%, in the European style.[353]

LUNG-CHHÜAN, KUAN AND KO WARES

The original Kuan wares and Lung-chhüan celadons from Chekiang province were reinterpreted at Ching-te-chen in the early Ming dynasty. However, the heyday for celadons took place in the late +12th and +13th centuries, at a time when *chhing-pai* 青白 wares were the main Ching-te-chen production. Lung-chhüan wares in particular became major competitors in Ching-te-chen's markets, and these thick-bodied, green-glazed wares were made at large and efficient kiln-complexes. They relied for their appeal on their sumptuous jade-like glazes and on the toughness of their porcellaneous bodies. The Lung-chhüan kiln area embraced the counties of Li-shui 麗水, Yün-ho 云和, Lung-chhüan 龍泉 and Chhing-yüan 慶元 in southern Chekiang province, and extended to *c.* 300 square kilometres. More than 400 sites have been excavated there by archaeologist Chu Po-Chhien 朱伯謙 and his colleagues since the +1950s.[354] The largest complexes were at Ta-yao 大窯 and Chin-tshun 金村; at Ta-yao alone kiln numbers more than doubled in the Southern Sung dynasty. In the Yuan dynasty Lung-chhüan continued to be active, for foreign trade was extremely important and even after the establishment of an imperial kiln at Ching-te-chen, Lung-chhüan kilns still needed to offer tribute to court.[355]

Despite their apparent differences Chekiang province celadon wares, from about the late +12th century onwards, and Ching-te-chen porcelains are close relations beneath the skin, a fact illuminated by chemical analysis.[356] As mentioned in Part 2, both manufacturing areas used body-materials that were based on quartz-mica porcelain stones, although at Lung-chhüan the porcelain stones were often deliberately adulterated with red-firing clays.[357] A general lime- to lime-alkali sequence also appears at Lung-chhüan, as the transition occurred from the grey siliceous stoneware bodies, with their Bronze Age associations, to the new porcelain stone based

[353] Vogt (1900), pp. 606–7.
[354] Vainker (1993b), p. 36.
[355] Mino & Tsiang (1986), pp. 22–3, Liu Hsin-Yüan (1993), pp. 40, 82.
[356] See Wood (1999), pp. 75–6, for a technological comparison between Ching-te-chen and Lung-chhüan wares.
[357] Chou Jen *et al.* (1973), p. 154. See also pp. 249–58 of this volume.

materials.[358] As happened at Ching-te-chen, the use of limestone as a major glaze-flux became important at Lung-chhüan at about the same time as the new body-materials were introduced. However, this transition occurred later at Lung-chhüan, apparently in the late +12th – +13th centuries, rather than the +10th century.

Perhaps the greatest difference between the two traditions lay in the considerable thicknesses achieved in Lung-chhüan celadon glazes at the time of their greatest quality, during the late Southern Sung and early Yuan dynasties. This too was made possible by the development of the lime-alkali compositions, as Chou Jen 周仁 and his co-workers explain:[359]

> The change from the use of a lime glaze to a lime-alkali glaze (at Lung-chhüan) in the Southern Song (Sung dynasty) period was clearly a creative step. It enabled the glaze to remain thick without running, and prevented the bubbles from becoming large. The result was that the glaze possesses a rich antique elegance and a unique jade-like air.

Many Lung-chhüan celadon wares have glazes that are about one millimetre thick, while some examples are 1.5 millimetres thick or more.[360] Up to four separate glaze-layers were used on some Southern Sung dynasty Lung-chhüan examples and these can show clearly on broken sections after firing.[361] These visible layers in the glaze sections are not confined to Lung-chhüan glazes. They are common in Kuan ware glazes, and also in some thickly applied Ching-te-chen monochromes such as the Hsüan-Te high-temperature blue.[362]

Glazes could be poured, brushed or even blown on to ceramic bodies. The most practical and straightforward way to coat raw or biscuit-ware with glaze is to dip the pieces into a well-stirred glaze-suspension, brought to the consistency of single cream. The porous ware then soaks up the water and leaves the suspended glaze particles to dry as an even coat on the surface of the object. If the ware is dipped again in the glaze when it is dry to increase the glaze thickness, both glaze-coats will tend to flake away, as the under-coat rehydrates, expands and loosens its grip on the ware. Reglazing while the first layer is still slightly damp can be effective, but timing of the dip must be judged exactly, which can be awkward for mass-production. Making the glaze-suspension thicker (that is with less water) so a thick glaze can be applied in a single dip, is also unsatisfactory as the thick glaze-coat tends to shrink and crack as it dries, and the glaze may not find its way into all the details of the form, such as handle-junctions.[363] Shrinking of the glaze during drying may also cause a phenomenon that is known in south China as 'flies' legs' (*tshang-ying chiao*

[358] *Ibid.*, p. 154.
[359] *Ibid.*, pp. 142–3.
[360] Kingery & Vandiver (1986a), p. 22, table 1.
[361] A good optical micrograph of a Ta-yao glaze is published in Sundius & Steger (1963), p. 430, fig. 39. This clearly shows four separate glaze-layers on each glazed surface.
[362] See Tichane (1978), p. 93, fig. 9.8, for a similar OM view of a Kuan ware glaze, again with four layers. Christine Lau (1994) notes from studying Hsüan-Te monochrome blue glazes in +1992: 'by using a hand-lens with 20× magnification, it can be seen that the glaze is multi-layered – at least four to five layers of blue glaze can be identified.'
[363] NW, personal experience.

蒼蠅腳), which are dimpled cracks, often with fine angled lines in their centres. These tend to appear in the fired glazes where original drying-cracks were sited.[364]

The problem of achieving suitably thick application with rather plastic glazes was solved ingeniously at Lung-chhüan by repeated applications of thin glazes to build a much thicker glaze-coat in as many as four separate layers. Finally, with all the layers complete, the whole vessel could be given its glaze firing, typically to about 1,230°C (±20°C) for fine Southern Sung dynasty examples.[365] This gave a smooth unblemished glaze of substantial thickness, with the interfaces between the layers contributing to the visual complexity of the glaze, although at a near subliminal level.[366]

This last phenomenon, the survival of glaze-layers after firing, is not entirely easy to understand as one would expect all layers to have the same composition, and to melt into a homogenous whole at full temperature, with no evidence of multiple glaze-application after firing. Analysis shows, however, that there are real compositional differences within these glazes and that they correspond to the separate glaze-layers, which on many examples are clearly visible at low magnification on broken sections.[367] In detail, the calcia and silica levels in the glazes tend to show a series of peaks as point-analysis scans from the body-glaze interface to the glaze surface, and this can give a clear indication of the number of layers used, provided that the object has not been over-fired.[368]

These calcia+silica peaks correspond to the surface of each glaze-layer and are often represented after firing by layers of wollastonite crystals that have grown within the glazes during firing and early cooling (wollastonite is calcium metasilicate with the formula $SiCaO_3$). Deeper within the each glaze-layer the more usual crystal-growth is anorthite (lime feldspar), which reflects the lower-silica, lower-lime and higher-alumina environments within these zones.

A number of proposals have been made to explain this effect. For instance, that low-lime and high-lime glazes were alternated in application,[369] or that clay dust from the workshop had accumulated on the raw glazed surfaces, in between glazing sessions.[370] Another proposal is that the soluble ingredients in the glazes had migrated to the surfaces in drying, locally changing their compositions.[371] Perhaps a

[364] Chou Jen *et al.* (1973), pp. 143–5.

[365] *Ibid.*, p. 154.

[366] The idea developed during the Southern Sung dynasty in Chekiang province for successive biscuit-firings on wares, is inferred from some biscuit-fired sherds of Kuan ware bearing sintered glazes, found at Chiao-than Hsia 郊壇下. See Chen Quanqing & Zhou Shaohua (1992), p. 367.

[367] Sundius & Steger (1963), p. 430, fig. 39.

[368] Sundius writes of a Sung dynasty Ta-yao glaze from Lung-chhüan that he examined: 'It contains varying amounts of remnants of quartz and lime, the later often surrounded by anorthite needles. The remnants are concentrated along thin strips in the thin glaze and the glaze is hereby divided into two or more layers, a sign of repeated application of the glaze raw mass.' Sundius & Steger (1963), p. 432. Vandiver & Kingery (1986b), p. 190, and p. 192, fig. 6, studied these changes in CaO contents through the thicknesses of Lung-chhüan glazes quantitatively, and found significant rises and falls in the calcia levels, of between 5.2–12% CaO in one example.

[369] Tichane (1978), pp. 164–5.

[370] Vandiver & Kingery (1986b), p. 191.

[371] Kingery & Vandiver (1986a), p. 85.

more likely explanation may be that the *insoluble* components in the wet glazes unmixed somewhat in the instant before they dried, leaving a mixture of calcium carbonate and quartz particles concentrated on their surface, while the micas stayed deeper within the glazes.[372] The bands richest in quartz and calcia encouraged the growth of wollastonite crystals in firing, while the micas and clays (both aluminous materials) promoted the high-alumina mineral, anorthite. In this scenario the same glaze compositions could have been used throughout.

However achieved, the practical effects of these phenomena, when combined with millions of fine bubbles and some unmelted batch material trapped within the stiff glazes, were to give thick Lung-chhüan glazes more complex microstructures than single thick coats of glaze could have supplied. This made the glazes remarkably jade-like in appearance. Indeed the microstructures of moderately fired Lung-chhüan glazes correspond rather closely to the two main types of jade: nephrite and jadeite. In the former the microstructure is fibrous (corresponding to anorthite), while the texture of jadeite is granular, and closer to crystallised pseudo-wollastonite.[373]

Colour parallels with jade are perhaps less exact. Most pre-18th-century Chinese jade is nephrite ($NaAlSi_2O_6$) and a translucent greasy white, often with a cream or greenish tinge. Very green jade (jadeite, *fei-tshui* 翡翠 or 'kingfisher' jade, $Ca_2Mg_5Si_8O_{22}(OH)_2$) is more abundant in China after the +1780s.[374] For this reason, early Chinese comparisons of ceramic glazes with jade were made as often with white porcelains as they were with southern celadon wares.[375] Nonetheless, modern experience of later (and greener) Chinese jades has extended our sense of jade's colour, and made parallels with Lung-chhüan glazes seem even more appropriate.

COLOURS, RAW MATERIALS, AND RECIPES FOR LUNG-CHHÜAN GLAZES

Chou Jen and his colleagues note that the alkali contents of Lung-chhüan glazes (4.8–7.6 KNaO) are often higher than might be expected from the local glaze stones. They offer two explanations for this effect, which are not necessarily mutually exclusive. The first is that less-weathered porcelain stones may have been chosen to make the glazes:[376]

> the Ta-yao china stone taken from the upper level of the pit differs from that taken from the lower level of the same pit. The former has deeply weathered and so the potassium and sodium content is lower, only about 3.1%, while the latter has been less weathered and thus contains as much as 5.2%.

[372] Wood (1999), p. 86.
[373] Walker (1991), p. 31.
[374] *Ibid.*, p. 22.
[375] Chen Baiquan (1993), pp. 13–14.
[376] Chou Jen *et al.* (1973), p. 143.

The second reason concerns the glaze-flux itself. Lu Jung's 陸容 *Shu Yüan Tsa Chi* (Miscellaneous Notes from the Garden of Beans and Peas, *c.* +1475) contains an account of clay selection, forming, lime-alkali glazes and firing procedures:[377]

> Green high-fired ware came first from Liu-thien 劉田 [probably present-day Liu-thien, near Lung-chhüan] . . . The clay dug from other areas was not as good as that from near the kilns. The glaze was composed with wood and leaf ash mixed with very fine limestone dust from the hills . . . Craftsmen first formed vessels on the wheel, or in moulds, then allowed the clay to dry, following which they glazed them placed them in saggers which they positioned carefully in stacks in the kiln. The wood fuel burned night and day, and the fire door was closed and sealed when the fire was red hot and without smoke. The firing was finished when the fire had completely burned down.

Citing this account, Chou Jen *et al.* propose that 'tree leaves' were used to burn the limestone for the glaze. As leaves tend to give more alkali-rich ashes than other materials, this may have helped to boost the alkali contents of the glazes. As for the iron contents of Lung-chhüan celadons, Chou *et al.* debate as to whether red clay was added to the glaze mix:[378]

> Was red clay added to the recipe of ancient celadon glaze? If this question is analysed simply from the standpoint of the iron content, a satisfactory answer is not easily obtained, as the iron contents of the ancient celadon glazes are all quite low . . . in the majority of cases between 1.0 and 1.6% . . . If a china clay with a low iron content . . . similar to Mao-chia-shan 毛家山 or Ling-ken 嶺根 china clay was used . . . then it is confirmed that red clay was added. But if a china clay with a comparatively high iron content, such as Ta-yao china clay were used then it would appear to be unnecessary to add red clay.

The authors also make the point that reproductions of Lung-chhüan celadon glazes that used recipes containing local red clays gave different (and rather more authentic) celadon colours than compositionally similar copies using small amounts of pure iron oxide to supply the necessary iron. Vogt too followed this path (that is the use of red clay for iron) in his successful celadon reproductions at Sèvres.[379] The superiority of red clay as a source of iron for greener celadons is probably due to the traces of titania that red clays introduce: titanium dioxide profoundly effects celadon colours at levels more than about 0.2%, moving them from their natural iron-blues to celadon-greens of a more typically Chinese tone.[380]

Chou Jen's speculation that Sung dynasty Ta-yao glazes may have been made without red clays in their recipes, simply relying on the iron already in the porcelain stones and glaze-ashes, may explain the unusually fine blue celadon colours associated with this kiln site. Such an approach would have given low-titania glazes that allowed fine iron-blue tones to develop in firing, and analyses of the best Ta-yao wares seem to confirm this low-titania principle (Table 107). Described as *kinuta*

[377] *Chekiang Thung Chih*, ch. 107 ('*Wu Tsang Chih*'), p. 28b. Quoted in Chhen Wan-Li (1972, 1976), p. 23. *CHSC* reprint (1997), p. 176.
[378] Chou Jen *et al.* (1973), p. 142.
[379] Vogt (1900), pp. 606–7.
[380] Ishii Tsuneshi (1930a), p. 357.

Table 107 *Analyses of Southern Sung dynasty Lung-chhüan celadons from the Ta-yao kiln: glazes and bodies*

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Total
Glazes											
Ta-yao[a]	67.2	14.3	0.07	1.2	10.0	0.6	4.2	0.1	-.-	0.2	97.9
Ta-yao[b]	68.1	15.5	0.02	0.9	10.4	0.7	3.8	0.15	-.-	0.2	99.8
Bodies											
Ta-yao	67.7	23.2	trace	2.4	trace	trace	5.6	1.4	-.-	-.-	100.3
Ta-yao	67.1	23.4	trace	2.0	trace	trace	5.9	1.5	-.-	-.-	99.9

[a] Vandiver & Kingery (1986b), p. 188, table 1.
[b] Chou Jen *et al.* (1973), p. 136, table 3.

wares 砧窯 in Japan, they used fine forms, pale greyish bodies, and thick blue celadon glazes.[381]

In their essential chemistry, Ta-yao blue celadons are classic lime-alkali compositions, and they correspond closely to the type of glazes developed later at Ching-te-chen (in the $+14^{th}$ century) for use with under-glaze blue painting.[382] Their low phosphorous levels tend to support the idea that limestone rather than wood ash was their main source of calcia, while the small traces of P_2O_5 still present in these glazes may represent some minor use of vegetal ash, as proposed by Chou Jen. Simple mixtures of this Ta-yao body-material with limestone would have produced glazes too low in silica and too high in alumina to be ideal, so related, but more siliceous, stones were probably used in the Ta-yao glaze recipes. If so, this would parallel the changes suggested for the glaze-making procedures used at Ching-te-chen through the same period.

Titania is certainly crucial in its effect on the colours of Lung-chhüan celadons, but overall iron oxide levels, the degrees of reduction that the glazes have received in firing, and degrees of melting are also vital influences. In addition to these familiar effects Chou Jen *et al.* also mention a possible yellowing influence on later (Ming dynasty) Lung-chhüan glazes from the same iron-sulphur chromophore that provides the brown in modern beer bottles, although they do not support this view with analysis.[383] This same possibility is raised (but again not tested) by Vandiver and Kingery when they discuss a yellowish layer they found on the surface of some Lung-chhüan glazes.[384] Thin superficial reoxidation may also have played some part in this effect, as this would have been fierce in dragon kilns, where the combustion-air

[381] See Mino & Tsiang (1986), pp. 192–7, for illustrations and discussion of these top-quality Lung-chhüan wares.
[382] Chen Yaocheng *et al.* (1986), table 2, p. 124.
[383] Chou Jen *et al.* (1973), p. 140. See Schreurs & Brill (1984), pp. 199–209, for an account of this effect in ancient glasses.
[384] Kingery & Vandiver (1986a), p. 85.

Table 108 *Lung-chhüan celadon glazes: Five Dynasties to Ming dynasty*[a]

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Total
Five Dynasties	59.4	16.0	0.4	1.8	16.0	2.0	3.4	0.3	0.6	-.-	99.9
Northern Sung dynasty	63.2	16.8	0.2	1.4	13.0	1.1	3.3	0.6	0.4	-.-	100.0
Southern Sung dynasty	68.6	14.3	0.1	1.0	10.0	0.4	4.3	1.1	0.1	0.14	100.0
Yuan dynasty	67.4	16.7	0.2	1.5	6.8	0.6	5.5	1.1	0.45	-.-	100.3
Ming dynasty	67.6	15.0	trace	1.4	6.3	1.7	6.5	1.1	0.1	-.-	99.7

[a] Chou Jen *et al.* (1973), p. 136, table 3.

was often forced to pass through white-hot, newly fired wares before burning the fuel introduced further up the kiln by side-stoking (see pp. 351–4).

Other kiln sites in the Lung-chhüan area made greener celadons. Sea-green and pea-green tones became particularly obvious in Yuan and early Ming dynasty examples, which are generally higher in titania than Sung dynasty wares. These later wares also show higher alkali contents in both glazes and bodies, which encouraged both more unctuous and glassier glazes.[385] Various stages of Lung-chhüan celadon glaze production, from the Five Dynasties to the Early Ming period, are summarised in Table 108.

Besides this change of colour Yuan dynasty Lung-chhüan wares became much larger, with greater use made of moulding; in the Ming dynasty wares became heavy and thick, with rather coarse decoration.[386]

Despite their great beauty, Lung-chhüan ceramics were never regarded as one of the 'Five Great Wares' and were not mentioned as frequently by connoisseurs as other Sung dynasty ceramics. Tshao Chao's ambivalent reference was typical:[387]

> Ancient blue-green pieces have fine, thin bodies. Those with kingfisher blue-green colour (*tshui chhing* 翠青) are valuable, those with pale green-blue (*fen chhing* 粉青) are less so. Very thick basins with paired fish design in the base and ring-handles at the rim are relatively cheap in price.

Nevertheless, Lung-chhüan ceramics gained an extremely wide market, both in China and abroad. Several kilns set up in competition to manufacture Lung-chhüan-style wares. For example, in the Sung–Yuan periods I-yang 益陽 in Hunan province was active, while the Liang-tzu-hu 梁子湖 kiln district of Hupei province was a major kiln centre with hundreds of kiln localities making Lung-chhüan style greenwares. Kilns in Fukien and Kuangtung provinces made huge volumes of greenwares for export from the Sung dynasty period onwards (see

[385] Chou Jen *et al.* (1973), p. 136, table 3.
[386] Li Dejin (1994), pp. 90–2.
[387] *Ko Ku Yao Lun*, ch. 3, p. 40a; David (1971), pp. 142, 305.

pp. 716–17).[388] Taxation was collected on white clay at Chhüan-chou in Fukien during the Southern Sung dynasty period, indicating the superior quality of raw materials used to make greenwares there.[389] In Kuangtung, kilns were so successful that they were still turning out imitation Lung-chhüan wares in the Ming dynasty.[390]

In Chekiang province itself, there was an attempt in the mid Ming dynasty to revive production of official wares there. In the Cheng-Thung reign period, kilns were set up at Chhing-yüan some 320 kilometres from Lung-chhüan. The experiment failed, as ceramics produced could not match the beauty of Sung dynasty wares.[391] As soon as the Chheng-Hua emperor usurped the throne in +1465 he recalled supervising officials[392] and by the late Ming dynasty Lung-chhüan kilns, unable to improve their wares, had sunk further into obscurity.[393] By the early Chhing period they were supplying low-quality ceramics to local clients only. That dynasty also saw ingress of potters from Fukien province to revive the Lung-chhüan industry, as Chou Jen *et al.* investigated and reported:[394]

> In the Hsien-Feng period, a number of people from Te-hua, Fukien are said to have come to the area of Mu-tai 木岱, Hsi-hsiang 西鄉, Lung-chhüan 龍泉 and set up kilns to fire rough porcelain and to have taught their techniques.

The potters from Fukien province introduced the practice of burning lime with rice-husks to make glaze-ash, and this approach was still being used in Lung-chhüan celadon workshops in +1973.[395]

KUAN WARE 官窯

At the same time as thick-bodied porcellaneous Lung-chhüan celadons were enjoying large-scale production in the Southern Sung and Yuan dynasties, another important celadon ware was being made in Chekiang province. This was Kuan ware, which had a more rarefied character and much higher status. By the mid +12th century several layers of glaze, 1–2.5 millimetres thick, were applied in separate firings (see pp. 259–66). Because of the thickness of the glaze-layers on later Kuan wares small spurs could stick, so the glaze was sometimes wiped from the footring and pieces were fired on pads. After firing, some reoxidation of the unglazed purplish-brown foot, and the ochre-brown mouthrim where glaze was thin gave rise to the famous description of Kuan ware having 'purple mouth and iron foot' (*tzu-khou thieh-tsu* 紫口鐵足).

[388] Ho Chui-Mei (1994b), pp. 109–10.
[389] *Sung Shih*, ch. 413 ('*Chao Pi-Yüan Chuan*'), p. 16.
[390] Ho Chui-Mei (1994b), pp. 109–10.
[391] *Lung-chhüan Hsien Chih*, ch. 3, p. 8.
[392] *Ming Ying-Tsung Shih Lu*, Thien-Shun 8th year, 10th month.
[393] *Kuang Chih I*, ch. 4, p. 70.
[394] Chou Jen *et al.* (1973), p. 143.
[395] *Ibid.*

Fully developed Kuan wares display a rather special combination of body and glaze, i.e. essentially thick lime or lime-alkali porcelain glazes on thin and relatively ferruginous stoneware bodies. The use of thick pale glazes on thin dark bodies represented a new departure for Chekiang celadon manufacture.

When the resources of Chekiang provinces are examined, three clays in particular can be associated with the production of high-temperature glazed wares in the province. The first was low-iron siliceous stoneware of classic southern style, used in the Chekiang area since the Bronze Age for making ash-glazed stonewares, and then on an enormous scale there for the manufacture of Yüeh wares 越窯. The second was a more aluminous dark-firing iron-rich stoneware, while the third was a light-firing micaceous porcelain stone, similar to those found near Ching-te-chen. As described on pp. 249–58, the last two materials were often combined to make Lung-chhüan celadon bodies.

During the very earliest phase of Southern Sung dynasty Kuan ware production at Hang-chou, some use seems to have been made of local and relatively low-iron siliceous stoneware materials of the Yüeh type.[396] Indeed, a small proportion of Kuan ware has a white body.[397] Most examples, however, exploited iron-rich stoneware clays that could fire almost black in strong reduction, and to a warm brown in oxidation. As discussed on pp. 264–5, it seems likely that this dark-firing material used for Hang-chou Kuan ware was a close relation to the red clays that were blended with porcelain stones in the Lung-chhüan area.

In some ways the use of this dark-firing material, together with a pale celadon-type glaze, represented an important departure from traditional southern ceramic practice, as the glaze seems to have contained neither the body-material nor any close relation to it. Judging from the numerous analyses that have been published of Kuan ware glazes, they were made from rather aluminous white-firing porcelain stones mixed with wood ashes, and their red clay contents were either very low or non-existent. Chemical analysis has also demonstrated the overwhelming compositional similarities that existed between Hang-chou 杭州 and Lung-chhüan Kuan-style wares. Analysis of Kuan ware *glazes* from both northern and southern Chekiang province also reveal them to be similar to those used on Ju wares from Honan province (see p. 583 table 109 and p. 605 table 121), the original models for the Kuan wares themselves (Table 109).

In greater detail, these glaze analyses show that Kuan wares used lime glazes, with calcia compositions that fall midway between the Yüeh and the Southern Sung dynasty Lung-chhüan types. However, Kuan glazes also tended to be above average in alumina, which gave greater firing stability to that found in Yüeh glazes, together with a tendency to form a smooth stony mattness from the microcrystallisation of the high-alumina mineral anorthite (lime feldspar) during cooling. Both

[396] Scott (1993b), pp. 16–17.

[397] Gompertz (1958), p. 41. The modern museum on the Chiao-than Hsia kiln site at Hang-chou displays sherds of both white-bodied and black-bodied type.

Table 109 *Kuan ware glazes and bodies*[a]

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Total
Glazes: Hang-chou											
Kuan 1	65.4	14.6	0.08	0.7	13.4	0.7	4.0	0.2	-.-	0.4	99.5
Kuan 2	64.8	14.5	-.-	0.8	15.9	0.7	4.5	0.2	-.-	0.3	99.7
Kuan 3	65.0	16.1	-.-	1.0	12.5	0.7	3.5	0.3	-.-	-.-	99.1
Kuan 4	65.6	16.2	-.-	0.8	12.1	0.9	4.5	0.3	0.2	-.-	100.6
Glazes: Lung-chhüan Kuan ware											
Kuan 1	64.3	12.2	-.-	1.3	16.4	0.7	4.3	0.3	-.-	-.-	99.5
Kuan 2	63.1	16.1	0.08	1.0	14.0	0.7	4.0	0.2	-.-	0.4	99.6
Kuan 3	65.8	14.7	tr.	0.8	13.4	0.2	4.85	0.3	0.01	-.-	100.1
Kuan 4	63.3	15.7	0.2	0.9	14.2	0.6	4.2	0.2	-.-	-.-	99.3
Bodies: Hang-chou											
Kuan 1	61.3	28.8	0.7	4.1	0.2	0.6	4.2	0.2	-.-	0.08	100.2
Kuan 2	66.55	23.1	1.2	3.0	0.3	0.2	3.7	0.3	-.-	-.-	98.4
Kuan 3	69.8	20.6	0.7	3.1	0.3	0.7	3.75	0.4	-.-	0.08	99.4
Kuan 4	70.0	21.2	1.0	3.2	0.1	0.4	2.6	0.2	-.-	0.09	98.8
Bodies: Lung-chhüan											
Kuan 1	64.2	25.2	0.8	4.5	0.2	0.6	4.0	0.1	-.-	0.13	99.7
Kuan 2	62.7	28.7	-.-	3.7	0.5	0.5	4.1	0.1	-.-	-.-	100.3
Kuan 3	64.9	24.2	-.-	3.6	0.5	0.2	4.7	0.2	0.04	-.-	98.3
Kuan 4	63.3	26.1	-.-	4.6	0.5	0.3	3.7	0.2	-.-	-.-	98.7
Glazes: Ju ware (north China)											
Ju	58.3	0.4	2.1	14.2	12.3	4.5	0.8	0.3	0.7	0.1	99.1
Ju	58.8	17.0	0.2	2.3	15.2	1.7	3.2	1.7	-.-	0.6	100.7
Ju	58.4	15.6	0.16	2.1	16.3	1.9	3.8	0.8	0.1	0.6	99.8
Ju-type (Alexander bowl in the British Museum)	63.6	15.6	0.1	2.3	12.4	1.9	3.1	0.9	-.-	-.-	99.9

[a] Chen Xianqiu *et al.* (1986b), pp. 163–4, tables 2–4.

effects (stability and stony mattness) depended on keeping the maturing temperatures for the glazes reasonably low, probably to within the 1,220–1,240°C range. Firing to these temperatures tended to leave some batch material undissolved in the glazes, where it encouraged the nucleation of anorthite, both at full heat and in early cooling. The needle-shaped anorthite crystals mimicked the structure of nephrite and encouraged Kuan ware's visual parallels with jade. With greater heat this same uncombined calcia could dissolve fully into the glaze where it operated as a flux, causing the glazes to become glassy and finely crazed. Both stony-smooth and glassy examples of Kuan ware survive in many collections.

The very low titania levels established for these glazes were vital for the glazes' colours. Together with their associated low iron oxide contents, they explain the

bluish or light cream tones typical of Kuan ware glazes. Glazes with these colours could only have been made from pure raw materials, such as porcelain stones, and calculation suggests that mixtures of the more aluminous styles of prepared Lung-chhüan porcelain stone (such as those from Ta-yao and other nearby kilns),[398] together with typical calcareous wood ashes, in about 7:3 proportions, were probably used. Recipes of this style give oxide balances that fall within the compositional range quoted for the 'Lung-chhüan Kuan 龍泉官' glazes in Table 109. In their fired qualities Kuan wares were perhaps the most sophisticated ceramics of the Southern Sung dynasty, so this proposed technology represents a remarkably simple, straightforward and direct approach to glaze construction.

LAYERED GLAZES

Of all Chinese classic wares, the potters making Kuan wares seem to have made the most creative use of multiple-layer glazing techniques, with many examples showing greater glaze-totals than the bodies they cover. This phenomenon has been described by Sundius,[399] Tichane,[400] Chen Xianqiu *et al.*,[401] Kingery and Vandiver,[402] and by Chen Quanqing and Zhou Shaohua.[403] Excavations at the Kuan ware site have also confirmed the practice of multiple refirings of biscuit-wares between glazing sessions.[404] The arguments presented for Lung-chhüan glazes, as to whether these successive glaze-layers were of the same or of different compositions, apply equally to Kuan wares, although, on balance, the judgement that the glaze-layers are of the same composition seems the more likely.

Thin dark bodies and thick pale glazes are two characteristics of Kuan and Ko wares 哥窯, while a third is the tendency for Kuan glazes to craze. Crazing is caused by glazes shrinking more than the clay bodies beneath, during the last stages of cooling. As glass has poor strength in tension, this causes the glaze-coat to crack into a network of fine lines, which multiply as the contraction disparity increases.[405] Crazing in Kuan glazes is due mainly to low silica levels in both body and glaze as, for the temperatures that Kuan wares are fired, 70% or more silica would normally be needed in bodies and glazes to avoid crazing. Table 109 shows that both Kuan bodies and glazes are closer to 65% SiO_2 in the fired material, so the material is notably lacking in silica. This, of course, is a purely technical judgement: the combination of glaze and clay that Kuan ware potters developed in the +12th century still stands as one of the greatest artistic achievements in Chinese ceramic history.

[398] Chou Jen *et al.* (1973), pp. 48–50.
[399] Sundius & Steger (1963), p. 438.
[400] Tichane (1978), p. 175.
[401] Chen Xianqiu *et al.* (1986b), p. 161.
[402] Kingery & Vandiver (1987), p. 221.
[403] Chen Quanqing & Zhou Shaohua (1992), p. 363. Chen and Zhou not only state that the separate layers were 'not the same', but that more fusible glaze compositions were used inside some Kuan ware vessels than without. *Ibid.*, pp. 363–7.
[404] Examined by one of the authors (NW) in +1989.
[405] See Singer & German (1974), pp. 47–54 (Chapter 11 'Glaze Fit'), for a concise discussion of crazing.

When crazing is praised for its aesthetic qualities, as is often the case with Kuan and Ko wares, it tends to be referred to in the West as 'crackle'. Crackle and crazing are essentially the same phenomenon, although 'crackle' tends to imply that the effect was deliberate. Attractive though crackle can be, it does weaken the wares substantially and crazed ceramics tend to have far less strength than their uncrazed equivalents. When thick-crazed glazes occur on top of thin bodies, as they frequently do with Kuan wares, there is even some risk that the vessels themselves might crack. However, optical microscopy by Robert Tichane has shown that glaze-cracks in Kuan ware soon peter out as they dissipate among body-grains and pores in the stoneware clay. Tichane suggests that the use of stoneware, rather than porcelain, was a much safer option for this particular combination of glaze and glaze-thickness:[406]

> if this body were vitreous, then the crack would propagate through the piece and cause failure. With a softer microcracked body the large cracks can be dissipated in several directions without leading to immediate failure. Naturally this situation will not have the strength of a vitreous body, but at least it will survive.

In very thick Kuan ware glazes different crazing systems can even appear at different levels within the glaze, which can add substantially to the visual complexity of its surface, and further evoke the character of jade. Some Kuan ware glazes also show the phenomenon of 'fish scale' crazing, where a few *horizontal* glaze-cracks run parallel with, rather than vertical to, the body. This must be related to the compositional layering so often observed in Kuan glazes: these layers may well have shrunk at different rates during late cooling, and encouraged horizontal as well as vertical cracking. Fish-scale crazing is also seen on some northern Ju wares, demonstrating a further parallel between these two famous types of imperial ceramic.

Perhaps the best evidence for the contemporary appreciation of crazing in Kuan and Ko wares is the occasional practice of staining the major glaze-crackle with a intensely black pigment to provide a network of fine black lines on a smooth light ground. By necessity, this would have happened soon after the firing, and most probably when the wares were still hot from the kiln, when the craze lines were relatively open. Ceramics can continue to craze for days, or even for years, after firing, and this secondary crazing system often appears as a finer network on Kuan wares, between the major crackle lines. This secondary crazing is often stained a lighter colour, perhaps deliberately or perhaps simply through use. These two crazing systems supplied the celebrated 'gold thread and iron wire' effect, so often admired in Kuan and Ko wares. How the fashion for staining the crackle began is not known, but one possibility is that it was first used as a 'rescue' process, designed to improve the appearance of accidentally oxidised pieces (see p. 266).[407]

[406] Tichane (1978), p. 89.
[407] Wood (1999), pp. 86–7.

CLASSIC NORTHERN GLAZES: YAO-CHOU, CHÜN AND JU, AND THEIR IMITATIONSN

NORTHERN CELADON-TYPE WARES

Kuan wares can be regarded as the culmination in southern China of ceramic principles pioneered and developed in north China, through a period that ran from the late Thang dynasty to the Tartar invasion of +1127. Fine northern celadon glazes were first made in Shensi province at the Yao-chou 耀州窯 kilns during the Five Dynasties period, and this advanced celadon technology then spread to many northern sites, particularly in Honan province and in southern Hopei. The imperial Ju wares 汝窯 of Honan province mark the zenith of northern celadon development, before the technology was brought south to Hang-chou in the Southern Sung dynasty. Northern Chün wares can also be regarded as part of this story, although the opal-blue Chün wares 鈞窯 were ceramics that southern potters found rather difficult to match, and impossible to improve upon.

In the later Thang dynasty (+8th century onwards) celadon wares of a rather rural style were made at the Huang-pao kilns 黃堡窯 in Shensi province, mainly in the form of plain ewers, bottles and bowls. Nonetheless the use of relatively iron-rich bodies at the Huang-pao kilns were an advance on the pale clays and fresh green ash-glazes of contemporary northern greenwares made in provinces such as Hopei, Honan and Shantung. The Huang-pao kilns also produced blackwares in lively style, with the dark-firing stoneware glazes perhaps based largely on the local loess.[408]

A few whitewares were also made at Huang-pao, and the lead-glazed *san-tshai* wares from the area were described on p. 500.

Kilns producing Yao-chou ceramics have been identified for some five miles along the Chhi-shui river 漆水, with the Huang-pao kilns being the most productive and the most creative. Even so, in their early days in the Thang dynasty, greenwares from this district were much less sophisticated than contemporary Yüeh wares 越窯 of southern China. That difference in quality was evident in the choice of fourteen examples of *mi-se* 秘色 Yüeh ware from Chekiang province, for inclusion with the hoard of precious objects for the crypt of the Fa-men temple 法門寺 in Shensi province, sealed in +874. The temple is only some 100 kilometres from the Yao-chou kiln sites (Table 111).

Despite the rather country style of early Yao-chou wares, chemical analysis shows the potentials for some Thang dynasty Yao-chou celadon glazes. Like many northern porcelain glazes before them, these glazes often employed much purer raw materials than the clays beneath. Some examples show titania levels low enough to have allowed fine bluish celadon colours to develop, had they been

[408] Wood (1999), p. 140.

Table 110 *Analyses of Thang dynasty 'teadust' and blackware glazes*

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Total
Yao-chou tea-dust glaze[a]	63.85	13.6	0.7	3.1	9.1	2.6	3.0	1.2	0.1	0.2	99.45
Yao-chou black glaze[b]	67.0	13.4	0.5	6.7	4.7	1.5	3.3	1.2	0.1	-.-	98.4
Sian 西安 loess[c]	65.6	14.6	0.6	5.4	6.8	2.3	3.3	1.4	-.-	0.3	100.3

[a] Huang Ruifu *et al.* (1992), p. 188, table 1.
[b] Yang Zhongtang *et al.* (1995), p. 76, table 3.
[c] Freestone *et al.* (1989), p. 261, table 1.

Table 111 *Huang-pao glazes and bodies: Thang dynasty*[a]

		Celadons									
Code	Dynasty	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Total
Glazes												
89	Thang	61.4	16.3	1.9	0.4	16.0	1.5	1.75	0.2	0.07	0.8	100.3
TQ1	Thang	61.7	15.6	1.8	0.3	16.2	2.35	1.6	0.4	0.1	-.-	100.1
TQ2	Thang	61.6	14.45	1.7	0.07	17.6	2.3	1.8	0.3	0.05	-.-	99.9
TQ3	Thang	59.7	17.3	1.3	0.04	16.9	2.3	2.0	0.4	0.01	-.-	100.0
Korean	Koryŏ celadon	59.6	14.1	1.4	0.1	16.0	2.7	3.8	0.8	0.4	0.7	99.6
Bodies												
89	Thang	66.5	26.2	2.2	1.55	0.4	0.8	1.6	0.1	0.01	-.-	99.4
TQ1	Thang	64.75	28.8	1.8	1.6	0.3	1.1	1.4	0.2	-.-	-.-	100.0
TQ2	Thang	63.4	29.8	2.15	1.7	0.4	0.9	1.5	0.3	-.-	-.-	100.2

[a] Luo Hongjie (1996), database.

applied to sufficient thickness and fired in good reduction. In fact some Thang dynasty Huang-pao glazes (for example, TQ2 and TQ3, above) show compositions that lie somewhere between such classic lime glazes as Hang-chou Kuan wares 杭州官窯 and Korean Koryŏ dynasty celadons. In practice, a number of factors discouraged full exploitation of these glazes. These included the use of rather poorly refined stoneware clays, the tendency for Thang dynasty Yao-chou celadons to be applied too thinly, the yellowing effects induced by the high-titania white slips often used to lighten the local clays, and less-than-efficient reduction in the wood-burning kilns.

In parallel with lime-glazed celadon wares the Yao-chou potters also manufactured a small amount of white porcelain in the Thang dynasty. Yao-chou whitewares used more advanced lime-alkali glazes, higher kiln temperatures, and kiln atmospheres that were more oxidised than reduced. So refractory was the Yao-chou whiteware body-material that it was not fired to full maturity until the Northern

Table 112 *Glazes and bodies of Thang dynasty Yao-chou whitewares*[a]

Code	Dynasty	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Total
Glazes												
TBG2	Thang	62.1	20.2	0.8	0.5	9.7	0.9	2.3	0.6	-.-	-.-	97.1
TBG4	Thang	61.6	18.5	0.7	0.4	10.2	1.7	3.3	1.3	-.-	-.-	97.7
Bodies												
TBS2	Thang	63.65	29.8	1.1	1.0	0.7	0.5	1.5	0.6	(0.6)	-.-	98.25
TBS3	Thang	67.4	27.0	0.6	1.0	0.4	0.5	1.6	0.4	(0.9	-.-	98.9

[a] Zhang Zhigang *et al.* (1985), poster-paper at the Second International Conference on Ancient Chinese Pottery and Porcelain, Beijing, 1985. See also Zhang Zizheng *et al.* (1985), pp. 23–4.

Sung dynasty, by which time coal had replaced wood as the main kiln-fuel in the district (Table 112).[409]

As manufacturing techniques developed at Huang-pao in the Five Dynasties period lime glazes began to be superseded by lime-alkali glazes, perhaps from experience gained with the local whitewares. Potters in Shensi province also applied their glazes to greater thicknesses, improved the preparation of their clays, and managed reduction-firing more successfully. Because of these advances the visual parallels between Five Dynasties Yao-chou wares, and the much later Koryŏ dynasty celadons, are now very obvious. Some early +10th-century Huang-pao glazes are also reminiscent in colour of the bluish glazes used on Ju wares of the late +11th to early +12th centuries, although the Yao-chou celadons are generally glassier.

During the Five Dynasties period some Yao-chou celadons were still of the old lime glaze style, while others were more like Northern Sung dynasty Ching-te-chen *chhing-pai* 景德鎮青白 glazes in their lime contents. A third group anticipated the lime-alkali glazes of Lung-chhüan 龍泉窯, and there are even a few examples of low-lime Yao-chou celadons that are similar in construction to Ching-te-chen porcelain glazes of the Chhing dynasty (Table 113). Whether these Five Dynasties compositions represent successive transitions, or whether they were often made simultaneously, is still difficult to establish. If the latter were the case then they may have been set in different parts of the *man-thou* kilns, with their lime contents matching differences in kiln temperatures. Such an approach (if used) would have anticipated the way that the 'glaze ash' contents of Ching-te-chen glazes were adjusted to suit the various temperature-zones within the egg-shaped kilns (for description of kilns see pp. 314–78).

The fine bluish Yao-chou celadons of the Five Dynasties period were applied to some plain undecorated forms, such as mallow-shaped dishes and simple cups, and also to some spectacular ewers, with their surfaces deeply embellished with

[409] Zhang Zizheng *et al.* (1985), p. 24.

Table 113 *Huang-pao glazes and bodies: Five Dynasties period*[a]

Code	Dynasty	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Total
Glazes												
High lime												
FD09	Five Dynasties	60.3	15.9	1.4	0.06	18.35	1.8	1.7	0.35	0.01	-.-	99.9
FD07	Five Dynasties	59.6	14.9	1.4	0.2	19.6	1.5	1.8	0.3	0.09	-.-	99.4
FD05	Five Dynasties	60.3	14.1	1.4	0.2	20.1	1.6	1.8	0.4	0.09	-.-	100.0
Lime												
FD01	Five Dynasties	64.2	14.9	2.2	0.2	14.0	1.5	2.4	0.3	0.2	-.-	99.9
FD03	Five Dynasties	65.6	13.9	1.8	0.2	13.8	1.9	2.45	0.35	0.06	-.-	100.1
FD04	Five Dynasties	64.2	14.9	2.2	0.2	14.2	1.5	2.4	0.3	0.15	-.-	100.1
Lime-alkali												
FD06	Five Dynasties	69.7	14.3	1.8	0.2	9.9	1.4	2.3	0.35	0.1	-.-	100.1
FD08	Five Dynasties	75.5	12.8	1.5	0.2	6.4	0.9	2.3	0.3	0.2	-.-	100.1
FD10	Five Dynasties	69.8	14.9	1.45	0.2	9.8	1.2	2.3	0.5	0.05	-.-	100.2
Bodies for above												
FD09	Five Dynasties	64.7	27.5	2.3	1.7	0.6	1.05	1.9	0.2	-.-	-.-	100.0
FD07	Five Dynasties	63.1	28.6	3.0	1.6	0.7	1.1	1.8	0.2	0.01	-.-	100.1
FD05	Five Dynasties	64.0	27.65	3.0	1.8	0.7	0.8	1.8	0.2	-.-	-.-	100.0
FD01	Five Dynasties	65.4	26.4	2.9	1.9	0.4	0.8	1.7	0.2	0.2	-.-	99.9
FD03	Five Dynasties	68.2	25.9	1.65	1.4	0.06	0.65	1.9	0.2	-.-	-.-	100.0
FD04	Five Dynasties	65.4	26.4	2.9	1.9	0.4	0.8	1.7	0.2	0.2	-.-	99.9
FD06	Five Dynasties	66.0	26.2	2.9	1.6	0.4	0.8	1.7	0.25	0.1	-.-	100.0
FD08	Five Dynasties	65.5	26.8	2.7	1.9	0.5	5.8	1.5	0.3	0.1	-.-	105.1
FD10	Five Dynasties	64.6	27.4	2.2	1.5	1.65	0.7	1.7	0.2	0.03	-.-	100.0
$WDHQ_2$	Five Dynasties	53.0	36.4	2.9	2.3	0.4	1.9	2.6	0.4	-.-	-.-	99.9
FD02	Five Dynasties	68.75	26.4	1.5	1.3	0.1	0.4	1.4	0.2	-.-	-.-	100.1
$WDHQ_3$	Five Dynasties	59.3	30.3	4.4	2.2	0.4	1.2	1.8	0.2	0.15	-.-	100.0

[a] Luo Hongjie (1996), database.

finely carved ornament. So successful was this latter carved style that it was used for some late (+10th century) Yüeh wares made in Chekiang province, together with a number of northern forms.[410] This marks something of a status-reversal *vis-à-vis* Yao-chou and Yüeh wares.

A recurring theme in Chinese ceramic history has been the creation of some particularly successful material or technique which then disappeared from use. The principle occurs in *mi-se* Yüeh wares of the +9th century, which often achieved body and glaze qualities comparable with fine Lung-chhüan wares of the +13th century, and then ceased production. The appearance, and then disappearance, of underglaze cobalt-blue painting at Kung-hsien 鞏縣 in the late Thang dynasty is another example, while the abandonment of fine bluish celadons at Yao-chou, in favour of more ordinary olive green examples in the Northern Sung dynasty, provides a further case in point.

[410] See Wood (1999), p. 44, for a +10th-century Yüeh ware ewer of this heavily carved style.

One reason proposed for the change to greener from bluer celadon glazes at Yao-chou is the replacement of wood with coal for kiln-firing that occurred at Huang-pao in the later +10th century, for the colour change could have been caused by less efficient reduction in coal-burning kilns.[411] Another reason might be the formation of iron-sulphur chromophores in the Northern Sung dynasty Yao-chou glazes, coal being a more sulphur-rich fuel than wood.[412]

Some adjustment to glaze compositions, i.e. from lower- to higher-titania glazes, might seem another reason for the change from blue-to-green celadons, but the evidence here is ambiguous (see Tables 114 and 115). Very low titania compositions were certainly used at Yao-chou in the Five Dynasties period for some fine and bluish Yao-chou celadon glazes, but analysis also shows that similar low titania levels continue for a number of Northern Sung dynasty examples.

The relative influences of these different factors on glaze colour at Yao-chou, in the later +10th century, are therefore unresolved. If glaze composition were the reason, then the change is more likely to have been deliberate. But if it came from the potters' need to alter the fuel for their kilns, perhaps through diminishing wood resources, and perhaps from improved efficiency in the local coal-mining industry, then it may have been unavoidable.

In terms of their essential chemistries the great majority of Yao-chou celadons of the Northern Sung to Yuan dynasties were of lime-alkali composition. It is also noticeable during this period that Yao-chou celadon *bodies* became rather higher in silica, perhaps to inhibit crazing in the glazes and thereby to improve both the look and the strength of the wares. Both improvements resulted in a more sophisticated product.

A small number of Northern Sung dynasty Yao-chou celadon glazes (Y-1, S7-2 and SQ3) have lower-lime compositions that would have been useful in hotter parts of the *man-thou* kilns, although it is possible that this role was taken to some extent by Yao-chou whitewares (Table 115).

These exhibit some of the lowest-flux (and therefore highest-firing) compositions yet established for northern whitewares, with maturing temperatures as high as 1,370°C being proposed for one example (SB glaze).[413] Kiln finishing temperatures depend on the final rate of temperature rise, but these analyses demonstrate the potential refractoriness of the Yao-chou whiteware material, and its consequent

[411] Li Guozhen *et al.* (1989), p. 285. However, results from establishing FeO/Fe_2O_3 ratios in Yao-chou glazes in successive dynasties have proved inconclusive. Very low ratios (for example, 0.02–0.04) that suggest near-oxidising conditions give the expected creams and grey-yellow colours typical of oxidised celadons. However, a number of bluish Five Dynasties glazes appear with FeO/Fe_2O_3 ratios between 0.1 and 0.5, while similar ratios in Northern Sung dynasty Yao-chou glazes give green and green-yellow glaze-colours. Titania contents might have thrown some light on this anomaly, but were not reported in the study. See Zhang Zhigang *et al.* (1995), pp. 60–5, see esp. table 6.

[412] See Chou Jen *et al.* (1973), p. 140, and Kingery & Vandiver (1986b), p. 85, for proposals for similar colouring effects in Lung-chhüan glazes. See also Schreurs & Brill (1984) for a discussion of the iron-sulphur yellow effect in glass. Henderson (2000), p. 176, writing of Yao-chou specifically, also suggests: 'The use of coal as a fuel source may have had an effect on kiln atmosphere with the introduction of sulphurous fumes which could have led to the development of yellowish iron-sulphur chromophore in some of the glazes and the use of saggers.'

[413] Zhang Zizheng *et al.*, poster-paper at the Second International Conference on Ancient Chinese Pottery and Porcelain, Peking, 1985.

Table 114 *Huang-pao glazes and bodies: Northern Sung and Chin dynasties*[a]

Code	Dynasty	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Total
Lime-alkali glazes												
Y-3	Sung	67.0	15.3	1.8	0.3	9.6	1.4	2.6	0.4	0.07	0.8	99.3
SP-1	Sung	67.9	14.4	2.2	0.2	9.4	2.1	2.8	0.7	-.-	-.-	99.7
247	Sung	69.1	13.95	2.1	0.3	8.6	1.1	3.1	0.4	0.1	0.7	99.5
Y-4	Sung	70.0	13.6	1.4	0.1	9.5	1.3	2.7	0.3	0.05	0.6	99.6
SQ1	Sung	70.6	14.0	2.2	0.1	7.9	1.75	2.95	0.4	0.09	-.-	100.0
SQ2	Sung	72.3	13.9	1.8	0.08	7.3	1.4	2.7	0.3	0.04	-.-	100.0
SQ4	Sung	68.5	15.6	2.8	0.3	7.2	1.5	3.5	0.5	0.1	-.-	100.0
SQ6	Sung	62.8	18.3	3.8	0.1	9.0	2.15	3.4	0.6	0.1	-.-	100.3
SQ7	Sung	67.7	21.4	2.7	0.06	7.0	2.25	4.1	0.7	0.07	-.-	106.0
Lower lime glazes												
Y-1	Sung	71.6	14.4	1.9	0.4	5.6	1.55	3.05	0.6	0.05	0.5	99.7
S7-2	Sung	73.1	15.65	2.4	0.2	3.9	1.3	2.75	0.4	0.03	-.-	99.7
SQ3	Sung	72.7	13.7	2.5	0.03	5.9	1.5	3.1	0.6	-.-	-.-	100.0
Bodies												
SQ5	Sung	56.6	34.6	1.9	1.8	0.6	1.6	2.0	0.4	-.-	-.-	99.5
SP-1	Sung	71.5	22.4	1.3	1.2	1.25	0.8	2.1	0.3	-.-	-.-	100.9
Y-4	Sung	72.2	20.3	1.7	1.2	0.4	0.8	2.6	0.35	-.-	0.1	99.7
SQ1	Sung	70.3	22.3	2.1	1.0	0.4	1.1	2.5	0.4	0.02	-.-	100.1
SQ2	Sung	68.9	24.2	1.8	1.1	0.6	0.9	2.2	0.3	0.03	-.-	100.0
SQ4	Sung	65.3	24.6	2.7	1.9	0.5	1.2	3.2	0.5	0.07	-.-	98.1
SQ6	Sung	58.2	29.9	4.3	2.2	0.6	1.4	3.0	0.4	0.2	-.-	100.2
SQ7	Sung	66.6	22.35	3.7	1.4	0.8	1.6	2.8	0.5	0.03	-.-	99.8
Y-1	Sung	70.2	24.6	1.4	1.3	0.2	0.6	2.4	0.3	-.-	0.04	101.0
S7-2	Sung	69.0	22.4	2.3	1.2	1.95	0.6	2.1	0.5	0.02	-.-	100.1
SQ3	Sung	71.6	21.9	1.4	1.0	0.1	0.9	2.75	0.3	-.-	-.-	100.0

[a] Luo Hongjie (1996), database.

Table 115 *Glaze and body of Northern Sung dynasty Yao-chou whiteware*[a]

	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	(rest)	Total
SB (glaze) Northern Sung	65.0	19.0	0.5	0.02	8.4	2.2	1.25	0.4	-.-	-.-		96.8
SB (body) Northern Sung	58.6	34.7	0.6	0.1	2.0	0.8	1.2	0.7	-.-	-.-	0.7	99.4

[a] Zhang Zizheng *et al.*, poster-paper at the Second International Conference on Ancient Chinese Pottery and Porcelain, Peking, 1985. See also Zhang Zizheng *et al.* (1985), pp. 23–4.

Table 116 *Analysis of Yao-chou* fu-phing *stone*[a]

	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Total
Fu-phing stone	65.3	12.1	1.2	0.2	6.6	3.3	2.5	1.4	-.-	-.-	92.6

[a] Guo Yanyi (1987), p. 17, table 6.

ability to bear the brunt of the kiln's greatest heat (i.e. close to the coal-burning fireboxes).

Raw Materials for Yao-chou Celadon Glazes

There is a tradition that the prime ingredient for the Yao-chou celadon was a local feldspathic sandstone called *fu-phing* glaze stone 富平釉石. This was a natural mixture of quartz, feldspar, clay and calcium carbonate, all valuable minerals in stoneware glazes.[414] Analysis of *fu-phing* stone shows that the rock is virtually a glaze and that only minor additions of silica, clay and a calcia-rich flux (such as wood ash or limestone) would have been necessary to transform the pulverised stone into a well-balanced celadon composition (Table 116).

This example of *fu-phing* stone, however, seems rather too high in sodium oxide to represent exactly the kind of rock that may have been used in Yao-chou glazes of the Thang to Yuan dynasties. Low soda contents seem to have been a consistent feature of Yao-chou celadons throughout this period.

Where phosphorous oxide is sought in the analysis of Yao-chou celadon glazes it tends to be found at levels typical of wood ash, which suggests that the glazes may have been fluxed with wood ash through most of their history. This may seem surprising considering the abundance of limestone in the Thung-chhuan 銅川 district and the acute shortage of wood in this part of China today. The presence of phosphorous in northern glazes presents a rather more complex problem than with southern wares, so a brief digression may clarify the issue.

Phosphorous in Southern and Northern Glazes

In south China the development of early greenware glazes from fly ash- to ash-glazes, to clay-and-ash glazes seems by far the most likely course. Besides the strong circumstantial evidence provided by the wares themselves, all analyses of southern stoneware clays, glaze stones and limestones made so far contain zero-to-negligible amounts of P_2O_5. For this reason the presence of more than about 0.3% P_2O_5 in southern high-firing glazes tends to be taken as a sign that vegetal ash was used in the glaze recipes. However, phosphatic limestones are not unknown in the world,

[414] Guo Yanyi (1987), p. 18; Li Kuo-Chen and Kuan Phei-Ying (1979), p. 362.

and some igneous rocks also contain P_2O_5 at 0.x levels. North China is a separate geological domain from south China, as it was once a discrete tectonic block, so it is worth examining northern raw materials for evidence of phosphatic materials other than ash. Bearing in mind a common difficulty with published analyses, namely that the absence of a figure for a particular oxide may mean merely that it was not sought by the analyst, P_2O_5 levels in non-ash northern ceramic raw materials still seem to be as low as in their southern counterparts.[415]

As the levels of phosphorous oxide in Yao-chou glazes seem to correlate positively with glaze-calcia levels, this rather suggests that the major source of calcia was also the main supplier of phosphate. Bearing these factors in mind, the main possibilities that might explain the P_2O_5 contents in Yao-chou celadons, are:

- The phosphorous came from vegetal ash, as the main glaze-flux.
- The phosphorous came from a phosphatic limestone, as yet unidentified.
- The phosphorous came from the use of a highly phosphatic wood or plant, used to burn the local limestone for glaze-making.

On balance, the first judgement still seems the most plausible, but future evidence may modify this view.

Whatever its source, the presence of phosphorous oxides in relatively viscous lime-alkali glazes, combined with slight overfiring, could well have encouraged the appearance of the larger 'seeds' (bubbles) that appear in some glassier examples of Yao-chou celadons. These can be produced by the breakdown of P_2O_5 to P_2O_3 at high kiln temperatures,[416] and such visible bubbles are typical inclusions in slightly overfired Yao-chou celadon glazes. As for glaze-application, many sherds of unglazed Northern Sung and Chin period biscuit-ware have been found at the Huang-pao kilns, which suggests that at least some the wares were biscuit-glazed. That technique was already practised at Huang-pao in the Thang dynasty on *san-tshai* 三彩 wares.[417]

SUNG DYNASTY YAO-CHOU CELADON GLAZES AND BODIES

Yao-chou stoneware bodies were higher in iron oxide than many northern stoneware clays, and one reason for the visual success of the Yao-chou celadon material

[415] For example, there is no mention of phosphate minerals in the detailed mineralogical examination made of a limestone, local to the Huang-pao area, presented in Li Kuo-Chen & Kuan Phei-Ying (1979), p. 362 and p. 361, table 1.

[416] Kingery & Vandiver (1983), p. 1273, found with Chün glaze replications: 'the role of phosphate in these glazes is related neither to the opalescence, nor to the iron colouration, but rather to its influence on bubble formation . . . The surface of bubbles in Grebenier replicas were found to have an increased phosphorus content, as compared with bulk glaze composition.' They also identify 'phosphate decomposition' as a major source of pore structure in true Chinese Chün glazes.

[417] Thang dynasty *san-tshai* and Sung and Chin dynasty celadon-ware biscuit sherds were shown to the authors at Thung-chhuan in +1995.

was some interaction of its moderately ferruginous clay with its celadon glaze. Where Sung and Chin dynasty Yao-chou glazes were applied very thinly, or where they had thinned in firing, an almost golden hue could appear in the glazes through some superficial reoxidation of their iron oxide contents. Yao-chou glazes were often applied in two coats, with a single coat supplying a golden-brown effect, while two coats produced fine celadon greens.[418] Single coats of glaze are seen most often inside tall vessels, and under the feet of bowls, where they were probably used for the sake of economy. Where the Yao-chou clay bodies were unglazed, warm brown colours tended to develop in the kilns, both at high temperatures and in cooling.

Slightly thicker Yao-chou glazes tended not to reoxidise: they appear pale green, rather than golden-brown, and this effect is heightened by the development of a pronounced white layer at the glaze–body interface. In broken sections of Yao-chou celadon ware this can often be seen with the naked eye, where it resembles a thin coat of white slip. Analysis shows the layer to be a product of the long firing-cycles typical of *man-thou* kilns, rather than a thin dip of white clay, and it consists mainly of anorthite, fine bubbles and glass.[419] Its practical effect was to lighten the celadon glazes where they were thinner (although not so thin as to reoxidise and turn to golden brown). This enhanced the contrast between the thicker areas of glaze, where it pooled in carved, combed and impressed designs.

Long firings in the *man-thou* kilns could also have induced a faint haze of anorthite crystals in many Yao-chou celadon glazes, which supplied an attractive waxen cast to the glaze-surface. Lively carved and combed decoration, the sensitivity of the glazes to thickness, heightened by the white anorthite inter-layers, and fine and fresh celadon colours, often seeded with bubbles, all combined to give Yao-chou celadons their outstanding visual quality. These wares were offered as obligatory tribute to the court in the early Sung dynasty period, alongside Hsing 邢, Ting 定 and Yüeh 越 wares,[420] but later in the Northern Sung dynasty the best Yao-chou was ordered as an official ware, alongside Ting and Ju ware, as described by a late Southern Sung dynasty source:[421]

> The present administration judged the white porcelain of Ting-chou unfit for use, and thus ordered Ju-chou to produce celadon ware. Thereafter the kilns in Thang-chou 唐州 in Hopei, Teng-chou 鄧州 and Yao-chou all followed this order.

LIN-JU WARES 臨汝

Yao-chou was imitated at several kilns in Honan province, famous among them Lin-ju (see p. 165). Material excavated from Lin-ju (in the Sackler Museum in Peking)

[418] Fan Dongqing (1996), pp. 24–6.
[419] Li Wenchao *et al.* (1992), p. 285.
[420] *Thai-Phing Huan Yü Chi*, ch. 59, p. 5, ch. 62, p. 4, ch. 96, p. 5. *Sung Shih* (*'Ti Li Chih'*), ch. 85, p. 20, ch. 86, p. 6, ch. 87, p. 4. *Yüan-Feng Chiu Yü Chih*, ch. 2, p. 13, ch. 5, p. 13. *Sung Hui Yao Chi Kao* (*'Shih-huo'*), 41:41.
[421] *Fu Hsüan Tsa Lu*, trans. in Ts'ai Ho-Pi (1989), p. 26, who discusses the variability of textual references on pp. 9–13, 27–9.

Table 117 *Analyses of Lin-ju celadon glazes*[a]

Glazes	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Total
Lin-ju	67.0	14.7	0.3	1.6	9.2	0.8	3.6	1.5	-.-	0.4	99.1
Lin-ju	66.7	15.3	0.3	2.5	8.6	0.7	3.8	1.7	-.-	0.4	100
Lin-ju	67.5	15.3	0.3	2.5	7.6	1.1	3.7	1.4	-.-	0.7	100.1
Lin-ju	67.7	14.5	0.2	2.4	8.55	0.8	4.2	1.6	-.-	0.45	100.4

[a] Guo Yanyi & Li Guozhen (1986b), p. 154, table 1.

demonstrates some visual differences between Yao-chou and Lin-ju glazes, indicating that Lin-ju wares tended to be more highly fluxed and faster-fired. For example, where the glaze runs thick in the deeper decoration it is very green and shiny, whereas on Yao-chou ware thick glaze is yellowish-green and more matt.[420] Lin-ju glazes tend to be more crackled than Yao-chou glazes, the latter containing more bubbles. Some typical compositions for Lin-ju glazes have been established (Table 117).

The most likely raw materials for Lin-ju celadon glazes would have been mixtures of an acid igneous rock with wood ash, perhaps with some minor use of clay and/or quartz to boost the silica and alumina levels of the glazes.

CHÜN WARES 鈞窯

As well as these good local versions of Yao-chou celadon wares, some kilns in Lin-ju county also manufactured wares in the Chün ware style. The main feature of Chün ware is its thick opal-blue glaze, and the Lin-ju Chün glazes show particularly fine pale-blue tones. Chün wares were made at a number of sites in Honan and southern Hopei provinces, from the Northern Sung dynasty until the early Ming period, with the best examples deriving from kiln sites in Honan such as Chün-thai 鈞台 and Yeh-chu-kou 野豬溝. The former is now near to the centre of Yü-hsien 禹縣 town and a modern Chün ware factory now operates close to the original Northern Sung dynasty workshops.[421]

Chün wares used clay bodies similar to those used for Yao-chou and Lin-ju wares, but their lime-alkali glazes show higher silica and lower alumina figures than most northern celadon examples, with the silica percentage in Chün glazes averaging about 71%, and alumina about 9.5%. Because of this slight, but consistent, difference from the celadon norm, Chün glazes tended to develop spectacular opal-blue colours from liquid–liquid phase-separation effects that had developed during early cooling. Those effects were often heightened and dramatised by painting the

[420] Excavated material from the site was inspected at the Sackler Museum by one of the authors (RK).
[421] Wood (1996), p. 56.

wares with copper-rich pigments.[424] The copper brushwork was applied to the dry glazes in broad strokes or washes, which then merged with the bluish Chün glazes at full heat.[425] Copper painting on Chün wares gave cloudy and diffused marks in purple, green or red (and sometimes all three colours together), providing striking contrasts to the thick opal-blue glazes beneath.

Northern celadons often show affinities with beaten-metal and lacquer forms, so tend to be finely made. Chün wares, by contrast, are more heavily thrown and turned, and have a total lack of carved or impressed decoration. Chün glazes were also applied to a considerable thickness in order to maximise their phase-separation effects. The thick glazes add substantially to the weight and substance of the wares. Despite their strong compositional relationships with celadon wares, and the wide distribution of Chün ware kiln sites, there seems no evidence at the moment for any Chün ware production at the Yao-chou kiln-complex.

LIQUID–LIQUID PHASE SEPARATION

Two quite separate effects appear to have disposed Chinese glazes to liquid–liquid phase separation, namely high phosphorous oxide levels (usually >1.5% wt.), and a particularly high ratio of silica to alumina, usually at least 7.1:1 in real weights. At some kiln sites, both effects occurred together, as in the phase-separated Chhang-sha 長沙 and Chhiung-lai 邛崍 glazes, discussed on pp. 534–5. However the lime glazes used at these southern sites would have run badly if fired high enough to develop the full 'Chün blues', an effect that needed the stability of lime-alkali bases to develop properly.[426] Most glass emulsion glazes from Chhang-sha and Chhiung-lai are cream or white, together with some that are milky-green from added copper oxide. Only a few over-fired examples show bluish tones, although turquoise blue-green colours (a Cu^{2+}–glass emulsion mixture) are quite common with the copper-containing glazes. Bluish glass-emulsion effects also appear on some early Chinese ash-glazed wares (both northern and southern), but only where the chemistries of the glazes were propitious, and gravity had caused the fluid ash-glazes to thicken in crevices or on ridges.[427]

Northern Chün glazes differ from these earlier examples, in that their opal blue colours owe much more to their silica:alumina ratios than their phosphorous oxide contents, which tend to be modest, at about 0.3 to 0.9%. This point was made convincingly by David Kingery and Pamela Vandiver at the First International Conference on Ancient Chinese Pottery and Porcelain, held at Shanghai in +1982, when they demonstrated that lime-alkali glazes could spontaneously develop

[424] See Kingery & Vandiver (1983), and Kingery & Vandiver (1986b) for the first full explanations of the 'Chün effect'.

[425] 'The purplish-red areas that accentuate the cloudy blue are formed by painting a solution containing copper on to the unglazed but fired pot.' Kingery & Vandiver (1986b), p. 105. In practice, this was probably a suspension rather than a solution.

[426] Chen Xianqiu *et al.* (1989), p. 313.

[427] *Ibid.*, pp. 31–7, provide a thorough overview of Chinese glass-emulsion glazes.

Table 118 *Analyses of Thang dynasty 'splashed' or 'speckled Chün' glazes*[a]

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Total
Lighter 'splashed' glaze TJ5	67.4	11.3	0.4	2.2	11.4	1.0	4.2	0.3	0.1	1.85	100.2
Blackware glaze TJ1	70.1	13.6	0.7	5.1	5.4	1.7	2.5	0.75	0.1	0.01	100.0

[a] Chen Xianqiu *et al.* (1985a), p. 29 (abstract) and data from poster-paper.

liquid–liquid phase separation if their oxide balances fell within certain limits. Furthermore, this process could operate quite well without any phosphorous in the system.[428]

ORIGINS OF CHÜN GLAZES

Opal-blue glaze-effects appeared regularly in north China in the Thang dynasty, often at sites that later became associated with Chün ware making. They are seen particularly on northern blackware glazes as deliberate broad and thick brushings of lighter glazes on black glaze-backgrounds. These thick brushings of lighter glaze merged with the black glazes in firing and developed true bluish or yellowish opalescence if taken to sufficient heat, probably to at least 1,250–1,280°C, and in oxidising-to-neutral atmospheres. It seems possible that the idea for this dramatic light-on-dark effect came from Thang dynasty potters observing the accidental 'splashes' of ash-rich glaze that often appeared on their open-fired blackwares in wood-burning kilns. These effects came either from ash-slag dripping from the kiln roof's interior, or from a build-up of ash on the sides of the wares most exposed to the draft of the fire.[429]

Such accidental effects seem to have been translated by blackware potters into a deliberate glazing-process, with the lighter glazes applied with a thick, heavily charged brush. In its most advanced form, lighter glazes were replaced by a resist medium. The whole black-glazed vessel was then dipped in an opalising top-glaze. This produced an overall opal-blue glaze, with some black brush-marks in the resisted areas.

So similar do some of these resist-decorated wares appear to true Chün glazes of the later +10th century that they may represent a transition between late Thang dynasty 'splashed' blackwares and the Northern Sung dynasty Chün ware style. It seems likely that Thang dynasty 'splashed' blackwares 唐鈞 used substantial amounts of wood ash in their lighter glazes. That view is supported by the one example of splashed blackware so far analysed (Table 118).

Although the ratio of SiO_2 to Al_2O_3 in glaze TJ5 is relatively high, its opalescence is more likely to have been caused by its high phosphorous level, which in turn was most probably supplied by a substantial content of wood ash.

[428] Kingery & Vandiver (1986b).
[429] Wood (1999), p. 141.

Table 119 *Analyses of northern Chün ware glazes: Northern Sung to Yuan dynasties*[a]

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	CuO	CoO	P_2O_5	Total
Kuan-thai site 觀台, *Hopei*													
Blue Chün glaze, Sung dynasty	70.7	10.1	0.4	2.1	10.3	0.9	4.7	0.3	0.07	0.01	0.05	0.4	100.0
Blue Chün glaze, Sung dynasty	72.0	9.5	0.3	1.85	9.4	0.8	3.7	0.03	0.05	0.01	0.05	-.-	97.7
Blue Chün glaze, Sung dynasty	72.4	10.5	0.3	2.0	10.0	1.2	3.8	0.4	-.-	0.06	-.-	0.65	101.3
Sites at Yü-hsien 禹縣, *Honan*													
Blue Chün glaze, Sung dynasty	70.7	9.5	0.4	1.75	10.6	0.8	3.8	0.55	0.07	0.02	-.-	0.3	98.5
Blue Chün glaze, Sung dynasty	70.5	9.9	0.3	2.1	11.0	1.2	3.85	0.5	-.-	0.03	-.-	0.7	100.1
Blue Chün glaze, Yuan dynasty	69.1	11.0	0.2	1.8	9.8	2.4	3.3	1.1	-.-	0.03	-.-	0.9	99.6
Lin-ju 臨汝 *site, Honan*													
Blue Chün glaze, Sung dynasty	68.7	9.5	0.3	1.6	13.2	1.6	2.6	0.1	0.05	0.01	0.04	0.8	98.5
Blue Chün glaze, Sung dynasty	70.1	10.95	0.5	2.4	9.6	1.0	4.0	0.4	-.-	0.01	0.01	0.3	99.3
Blue Chün glaze, Sung dynasty	72.7	9.9	0.3	1.2	8.8	1.6	3.6	0.9	0.1	-.-	-.-	0.9	100.0

[a] Guo Yanyi & Li Guozhen (1989), pp. 70–1, table 1.

Table 120 *Analyses of green Chün ware glazes*

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	CuO	CoO	P_2O_5	Total
Green Chün glaze[a]	67.0	15.7	0.3	0.6	11.7	trace	2.6	1.6	-.-	-.-	-.-	0.6	99.5
Green Chün glaze[b]	64.4	14.0	0.2	1.9	10.1	1.5	3.8	2.6	-.-	-.-	-.-	0.7	98.6

[a] Sundius & Steger (1963), p. 416.
[b] Vandiver & Kingery (1985), p. 191, table 3.

In later true Chün glazes no black base-glaze was used and the opalising glazes were simply applied to good thicknesses. Phosphorus oxide levels in these true Chün glazes tend to be relatively low, and their silica contents higher than TJ5. This suggests that the glazes' liquid–liquid phase separation, and their associated opal-blue opalescence, depended more on the glazes' SiO_2:Al_2O_3 ratios, rather than the levels of phosphorous oxides that they contained (Table 119).

It can be seen from Table 119 that Chün glaze compositions varied little from kiln site to kiln site. This was most probably because their optical blue colours were so dependent on the rather exact balances of silica to alumina that the glazes contained. The lime-alkali basis of the glazes also suited Chün ware technology well, because of their good stability at high temperatures. Maturing temperatures for Chün wares were probably in the 1,280–1,300°C range, and the majority of the wares were fired in reduction.[430]

'Green Chün' Ware

An interesting exception to the compositional consistency described above occurs with the glazes of 'green Chün' wares. These share the strong forms and sturdy throwing of ordinary Chün wares, but they have thick, slightly turbid, green celadon glazes. Green Chüns are thought to derive from the same districts as some blue Chün wares, with Lin-ju considered as one possible source, and can occasionally feature copper-red brushwork.[431] Their lime-alkali compositions are more aluminous than Chün glazes and consequently non-opalising. They demonstrate the kinds of colours that iron oxide and titania should have provided in Chün glazes, had these solution-colours not been overwhelmed by the optical-blue glass-emulsion effects. Because of their distinct compositional differences from regular Chün wares it seems likely that green Chün wares were a deliberate and separate ceramic style, rather than simply mis-fired Chün-blues (Table 120).

[430] Modern Chün glaze reproductions, made to the same compositions as the Chinese originals, certainly fire to these temperatures, but the slow finishing rates of traditional *man-thou* kilns may have made the finishing temperatures of the Chinese kilns some 50°C lower than this proposed range.

[431] An example in the Shanghai Museum is given this Lin-ju provenance, observation by the authors in the museum galleries.

Optical examination of Chün ware glazes shows that they tend to lack the internal layers seen in many Lung-chhüan and Kuan examples,[432] and this view is confirmed by spot-analysis, as it tracks from the glaze–body interface to the glaze surface.[433] Chün glazes therefore appear more compositionally homogenous than southern glazes of equal thickness, and may well have been applied to biscuit-wares as single coats of thick glaze. This was mentioned as a hazardous strategy in connection with Lung-chhüan glazes, but the low alumina levels in Chün ware glazes show that the raw glazes contained low contents of plastic minerals, such as clays and micas, which in turn means lower shrinkages of the wet glazes in drying. Nonetheless, some Chün glazes still occasionally cracked as they dried on the wares. These cracks often survived as 'earth worm trails' (*chhiu-yin tsou-ni wen* 蚯蚓走泥紋) in the fired glazes, a 'fault' that has become one of the many admired features of the ware.[434]

Other Qualities in Chün Wares

Liquid–liquid phase separation, in early cooling (*c.* 1,100°C), provided the opal-blue cast to Chün ware glazes, with the spherules of separated glass being richer in calcia iron and copper than the glaze's glassy matrix.[435] Faster-fired and cooled-quickly Chün glazes appear bluish, but somewhat glassy. However, with enough time at high temperature these calcia-rich spherules could provide the 'seeds' for wollastonite crystals to grow, which tended to develop in long chains, giving whitish vertical streaks within the bluish glazes.

Where Chün glazes ran thin in firing (for instance at rims, on handle-edges, or over moulded features) the bluish opalescence disappeared and the glazes then appeared more like celadons. This is usually explained by the glazes' dissolving some body-clay in these areas, with the extra alumina from the clay bodies' preventing glass-emulsion effects from occurring. This same phenomenon has been used to explain the brownish-green character of the glazes beneath many Chün ware vessels.[436] These thinner glazes were often brushed on in a cursory way, and were not thick enough to develop true Chün blues.

The Imitation of Chün Type Wares at Other Kilns in Northern and Southern China

Chün ware became so popular that, like Yao-chou ware, it was imitated by kilns in south China in the Southern Sung and Yuan dynasties. 'Chün types' have been

[432] Sundius & Steger (1963), p. 410, figs. 30 and 31.
[433] Vandiver & Kingery (1985), p. 196, fig. 8.
[434] The first accurate explanation for this effect was given by Fong Chow in +1950: 'The "earth-worm tracks" are actually mud cracks of the raw glaze which appear after the biscuit has been dipped in the glaze.' Fong Chow (1950), p. 92. This view was confirmed by research in Shanghai in +1960. Chou Jen & Li Chia-Chih (1960a), p. 104.
[435] Kingery & Vandiver (1983), p. 1272.
[436] Wood (1999), p. 123.



Fig. 146 Flower pot with Yung-cheng mark in imitation of Sung dynasty Chün ware

found at Hang-chou 杭洲, Ning-po 寧波, and Chin-hua 金華 in Chekiang province,[437] and at Liu-chheng 柳城 and Yen-kuan 嚴關 in Kuangsi province.[438] By the Yuan dynasty Chün-style wares had became widespread and appeared also at traditional Tzhu-chou kilns 磁州窯 in Hopei province (see p. 172).[439] The practice of firing many wares at the same kiln was common, while strict control of personnel was maintained and ceramic taxes were collected.[440]

Chün was a robust, 'popular ware' in the Sung and Yuan dynasties and was thus not used at court nor mentioned in connoisseurly writing of the period. By the late Ming dynasty, however, its intrinsic beauty had won commendation and it was deemed to be one of the 'Five Great Wares'. At least as early as the Wan-Li reign period, Chün ware was acquired for the palace, and in the Chhing dynasty the practice of inscribing imperial hall names on items was commonplace. This

[437] See Kung Chhang (1984).

[438] Samples of Chün ware from Kuangsi province were brought to the Conference on Ancient Chinese ceramics at Shih-chia-chuang in October +1997, and examined by one of the authors (RK). They had light grey body and speckled blue glaze, some pieces being splashed with underglaze iron-brown rather than copper-red. They were not fired in saggers, but stacked using large blobs of clay as separators.

[439] *Chung-chou Tsa Tsu*, ch. 21, p. 2a, mentioned specifically very beautiful Chün wares made during the Chih-Yüan reign period, at a time when connoisseurship was advanced and the relevant kilns had long ago 'fallen into ruins'.

[440] *Yuan Shih*, ch. 94 ('*Shih Huo Chih*'), p. 31. *Yuan Tien Chang*, ch. 22 ('*Tung Chih*'), recorded the number of kiln workers and percentage of tax received under the jurisdiction of Chün-chou officials in +1268. Cf. Otagi (1987), pp. 342–5.

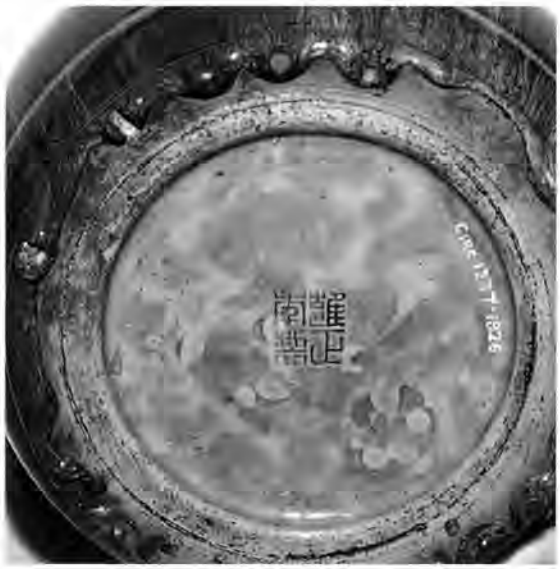


Fig. 147 Flower pot with Yung-cheng mark in imitation of Sung dynasty Chün ware

particularly applied to a category of Chün ware comprising large, moulded pieces for plant cultivation, such as flower pots, stands and bulb trays.

Emperors admired Chün glazes and sought to have them copied at the imperial factory at Ching-te-chen. Orders were initiated by the Yung-Cheng emperor in +1729 when Thang Ying 唐英 dispatched Wu Jao-Phu 吳蕘圃 to investigate traditional Chün ware glaze formulae from potters, presenting Wu with a farewell poem for his journey to Chün-chou 鈞州. By +1730 Ching-te-chen was successfully making imitation Chün, for Nien Hsi-Yao 年希堯 was able to select twelve large and small incense burners for imperial inspection. The verdict was favourable, commending their fine quality and asking Nien to make more similar items; further requests for small flowerpots followed in +1731. The Chhien-Lung emperor favoured both imitation Chün, and wares with yao-pien 窯變 glazes.

Yao-pien has been translated as 'flambé glaze', a description of phase-separated glaze that was generally blue streaked with purple and red (see p. 569). Many such pieces were sent to court. In +1743 Thang Ying presented 26 items, and was subsequently told in +1744 that *yao-pien* was no longer required. However, by +1747 orders were received to make a figure of Kuan-yin 觀音 in *yao-pien*, and were repeated in +1748. Perhaps the reason that such extraordinary figures do not survive is explained by the fact that Thang was subsequently accused of lacking in 'sincerity' (*chheng* 誠) in failing to produce Kuan-yin statues. In +1754 huge Chün ware cisterns were required for the Summer Palace Yüan-ming Yüan 圓明園 at Peking.[441]

[441] Fu Chen-Lun & Chen Li (1982), pp. 21–2, 64–5.

Testing of a small number of Yung-Cheng and Chhien-Lung period Chün wares revealed intense experimentation in reproducing glaze effects, suggesting involvement of glaze research workshops at the imperial factory at Ching-te-chen (see p. 570). Indeed, the description of the late Chhing dynasty factory layout included one specific workshop devoted to grinding colours used to reproduce ancient Chün ware.[442] Effects were achieved by applying three completely different glazes to the inside, outside and foot of vessels to simulate contrasting effects achieved through firing on genuine Chün ware. Chhing dynasty glazes were high firing, but unlike Chün ware were modified with small percentages of lead.[443]

Kilns in other provinces, such as I-hsing 宜興 in Chiangsu and Shih-wan 石灣 in Kuangtung introduced ceramics with phase-separated glazes in the +18th century, inspired by Sung dynasty Chün wares. The early greenwares and *chhing-pai* wares of Kuangtung province are mentioned on pp. 556–7, and the specialist tile and figurine business on pp. 521–2. Figural ceramics used high-iron clays from Shih-wan mountain 石灣山, kaolin, and other stoneware clays from the local area. Alongside architectural ceramics, kilns at Shih-wan made vessels, starting also in the late Ming dynasty and continuing down to the present day. Their speciality was phase-separated glazes, that probably started (as did glazed wares at I-hsing, so called '*I Chün* 宜鈞') with attempts to imitate Sung dynasty Chün ware. '*Kuang Chün* 廣鈞' ware that has been analysed demonstrated a coarsely prepared, underfired body. Unlike earlier Chün wares, it bore two layers of glaze, a thin brown underglaze and a thick top glaze coloured with copper and iron. The glazes were low-temperature lead glazes, fired in the range 1,020–1,150°C, and fluxed with large amounts of plant ash to give a lime glaze with high CaO content. These were glassy, non-crystalline glazes primarily coloured with compounds of copper and iron.[444] Other *Kuang Chün* ceramics from Kuangtung province were higher fired, and were typified by a hard, red-brown dark body. The subtle effects obtained on *Kuang Chün* gave way to more shiny glazes, their opalescent streaks and splashes probably aided with the addition of extra minerals to the surface of the glaze.

Kuangtung province wares have been admired and collected since the +19th century. *Ching-te-chen Thao Lu* (+1815) assessed them thus:[445]

> For all the elegance and beauty of their colours and the refinement of their glazes and polished sleekness, they are not the equal of porcelain, for they cannot avoid knife marks and unglazed patches.

The early +20th-century scholar Hsü Chih-Heng 許之衡 wrote:[446]

> The Kuang kiln 廣窯 was built at Yang-chiang 陽江, Chhao-chhing 肇慶, Kuangtung province, after the Sung dynasty imperial court had moved south. The kiln employed a

[442] Bushell (1896), p. 153.
[443] Innovative solutions to Chhing dynasty Chün and *yao-pien* glaze manufacture is reported in Kerr (1993).
[444] Yang Zhaoxi *et al.* (1989), (1995).
[445] *Ching-te-chen Thao Lu*, ch. 7, p. 10a.
[446] *Yin Liu Chai Shuo Tzhu*, ch. 2, pp. 259–60.

coarse brown clay to make wares of sky-blue colour whose surface and colour was uneven. The thick areas of glaze could be indigo, thinner areas grey-blue, while unglazed areas were yellowish-brown. In general they copied Chün ware but were different in that they had no red splashes or crab-claw marks like Chün ware . . . The name Kuang kiln is synonymous with that of Shih-wan 石灣, a village in Fo-shan 佛山, Nan-hai county 南海縣, that had already moved there in the Ming period.

In spite of the fact that Hsü was a native of Kuangtung province his account was not entirely accurate, for imitation Chün wares were not made at Shih-wan until the end of the Ming dynasty, and there is no evidence yet that there was ever a connection between Shih-wan and Yang-chiang.[447] Nevertheless, his description of the exciting glaze effects achieved through phase-separation on Kuangtung wares is accurate.[448]

Thao Ya (Ceramic Refinement, +1910) reflected on the ridiculous fact that Japanese collectors would pay more for Kuangtung wares than for genuine Chün. The writer's explanation is that they believed the wares to have been created by Japanese potters who went to China, a xenophobic view typical of the author of that work. Many references to Kuangtung wares make it clear that they were widely available in the antique shops of Peking in the early +20th century.[449]

Ju Wares 汝窯 and Glazes

Returning to north China and to classic wares of the Sung dynasty, glazes on China's premier imperial ware will be considered next. One of the most important sites for the making of Chün ware was in Lin-ju county, Honan province. This district has also been identified as a source for the celebrated celadon-glazed stoneware called Ju ware (see also p. 169).

Ju ware is finely made celadon-glazed stoneware with a relatively thick iron-blue glaze of great beauty. The body is rather pale and slightly underfired examples of northern stoneware that tends to show a grey-brown 'incense-ash' colour where it is exposed, although most Ju wares were fired on fine clay-spurs and are consequently almost fully glazed. Ju ware glazes are usually crazed and a few examples show the curious 'fish-scale' crazing mentioned in relation to later Kuan wares. Most Ju wares are undecorated and rely for their presence on simple but very subtle forms, some of which relate to the best quality of Northern Sung dynasty lacquer. One interesting group, however, bears elegant, incised designs of flowers or dragons that range across the whole surface.[450]

Despite the great rarity and status associated with this imperial ceramic, the technology of Ju ware seems rather straightforward. Ju wares used typical high-alumina

[447] Ceramics *were* made at Yang-chiang during the Northern Sung dynasty, and at Shih-wan during the Thang and Northern Sung dynasties. These were only two of more than 100 sites in Kuangtung province that made ceramics, from the Neolithic onwards. See Tseng Kuang-I *et al.* (1979).

[448] Tseng Kuang-I *et al.* (1979), pp. 132, 185.

[449] *Thao Ya*, ch. 1, pp. 21b, 46b, ch. 2, pp. 9b, 16b, 20a, 45a-b. Sayer (1959), pp. 37, 73, 88, 98, 103, 140–1.

[450] For a discussion of decoration on Ju wares, see Scott (1998), p. 50.

Table 121 *Compositions of Ju ware glazes compared with Yao-chou and Korean celadons*

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	Total
Ju ware glaze[a]	58.4	15.6	0.2	2.15	16.3	1.9	3.85	0.8	0.1	0.6	99.8
Ju ware glaze[b]	58.8	17.0	0.2	2.3	15.2	1.7	3.2	0.6	-.-	0.6	99.6
'Alexander bowl' in the British Museum[c]	63.6	15.6	0.1	2.3	12.4	1.9	3.1	0.9	-.-	-.-	99.9
Five Dynasties Yao-chou	60.3	15.9	0.06	1.4	18.35	1.8	1.7	0.35	0.01	-.-	99.9
Five Dynasties Yao-chou	59.6	14.9	0.2	1.4	19.6	1.5	1.8	0.3	0.1	-.-	99.4
Five Dynasties Yao-chou	60.3	14.1	0.2	1.4	20.1	1.57	1.8	0.40	0.1	-.-	100.0
Korean Koryŏ celadon	58.1	13.9	0.2	1.4	19.9	1.8	2.9	0.5	0.4	0.9	100.0
Korean Koryŏ celadon	59.6	14.1	0.1	1.4	16.0	2.7	3.8	0.8	0.4	0.7	99.6

[a] Wang Qingzheng (1991b), p. 89.
[b] Guo Yanyi & Li Guozhen (1986), p. 154, table 1.
[c] Pers. comm. Ian Freestone, Department of Scientific Research, the British Museum. For significance of the Alexander bowl see p. 178.

northern clays, and rather aluminous lime glazes that were low in titania. There seems little if any use of the clay body in the glaze recipe, which was probably based largely on some low-titania igneous rock, such as a granite. In this sense, Ju ware glazes relate both to Five Dynasties Yao-chou celadons of the lime-glaze type, and also (although perhaps by coincidence rather than by influence) with some contemporary Korean celadons (Table 121).

Ju ware was finely potted, but the two qualities that attracted most admiration and attention were its blue-green, unctuous glaze and its rarity. Both the difficulty of collecting specimens, and the exact colour and texture of Ju glaze, were often commented on by connoisseurs. Chou Hui 周輝 noted it was difficult to obtain even so shortly after the time of its manufacture, because only pieces rejected for court use could be sold.[451] Tshao Chao 曹昭 admired its thin, fine body, its extreme rarity and the nature of the 'crab's claw' markings (*hsieh-chao wen* 蟹爪紋) in the greenish-blue glaze.[452] Kao Lien 高濂 described the glaze as being egg-white, thick and with a curdled effect like congealing lard, and having within it faint marks including 'crab's claw'.[453] In later times scholars mistakenly reported on the beauties of Yuan dynasty Ju ware, the great Chhing dynasty encyclopaedia *Ku Chin Thu Shu Chi Chheng* (+1726) going so far as to say that the very best wares were made in the Chih-Yüan reign period.[454]

[451] *Chhing-po Tsa Chih*, ch. 5, p. 3a.
[452] *Kō Ku Yao Lun*, ch. 3, p. 38a; David (1971), pp. 139, 307.
[453] *Tsun Sheng Pa Chien*, ch. 14, p. 41b. Similar comments were included in other texts, for example, *Chhing Pi Tshang* (*c.* +1595), ch. 6, p. 9a. Bushell (1910), p. 41, summarises Ming dynasty descriptions of Ju ware.
[454] *Cheng-Te Ju-chou Chih*, ch. 2 ('*ku chi*'), p. 9. *Ku Chin Thu Shu Chi Chheng*, ch. 481. Cf. Li Min-Chu (1996), pp. 205–13.

One feature of the Ju glaze that was constantly mentioned from early times, was the inclusion of agate in the glaze mix.[455] Although at first sight this may seem unlikely, in fact the main component of agate is silicon dioxide (SiO_2), with associated iron, both useful compounds for forming and colouring a reduced celadon glaze. Agate therefore gave no real technical advantage but did no harm either, and its inclusion may have had talismanic powers in the minds of local potters.[456] Several Sung dynasty sources detailed the mining of large quantities of high-quality agate in the locality. *Sung Shih* (+1345) recorded that agate was mined at the town of Chhing-ling 青嶺, only about five miles from the Ju kiln site, in the Cheng-Ho reign period.[457]

SUMMARY OF PART 5: 'GLAZES'

Certain Sung dynasty wares such as Ju represent the culmination of 2,500 years of experience and experiment with high-fired glaze compositions in China. The real origins of Chinese glaze technology, however, are found in the early Bronze Age, when thin and mottled yellowish-green ash-glazes began to appear in south China on some wood-fired stonewares.[458] These were true high-temperature glazes and they formed the foundations for the great ash-glazing tradition that spread throughout southern China during the Bronze Age and was then taken up in north China in the early +6th century. Ash glazing in the south reached its zenith in the +4th to +11th centuries with the Yüeh wares of northern Chekiang province, after which limestone gradually replaced wood ash as south China's main glaze-flux.

China is unusual in starting its glaze-history with high-fired rather than with low-fired glazes, and it was not until the Warring States period that low-fired glazes, fluxed with lead and barium oxides, were at last developed in the country. This was some 5,000 years later than any earthenware equivalents in West Asia, and 1,000 years later than China's first ash-glazes. High-lead glazes were later used extensively on Chinese burial wares in the Han and Thang dynasties. In the post-Thang era brilliantly coloured lead glazes continued to be employed for burial wares and also for architectural ceramics. By the early Ming dynasty, coloured lead glazes were also applied to pre-fired porcelains to create pure and bright monochrome glazes, some of which saw use in imperial rites. This overglaze enamel technology appears to have been borrowed from north China, where it had been applied to white-slipped and glazed stonewares as early as the late +12th century.

The practice of using sodium or potassium oxides (the 'alkalies') as major glaze-fluxes has been the essence of Near Eastern glaze technology from the –5th millennium through to modern times. It did not occur in China until the Eastern Han

[455] For example, *Chhing-po Tsa Chih*, ch. 5, p. 3a, *Kò Ku Yao Lun*, ch. 6, p. 6a, ch. 8, p. 6a, *Tzu Thao Hsüan Tse Chui*, ch. 1, p. 34. The reference was doubtless copied from one text to another, and also occurs in Chhing dynasty references.

[456] Cf. Zhang Zhongming & Zhu Changhe (1995), pp. 307–8. Ts'ai Mei-Fen (1996), pp. 115–20, suggests a link between glass and Ju ware, and cites the use of agate as furthering the connection.

[457] Yeh Che-Min & Yeh Phei-Lan (2002), pp. 20, 40.

[458] Zhang Fukang (1986b), pp. 40–5.

dynasty when high potassium oxide levels occurred in some rare glazes from Chhang-sha (see pp. 464–6).[459] True visual matches to Near Eastern alkaline glazes were not achieved until the Thang dynasty, however, when potters in north China experimented with low-firing turquoise alkaline glazes. These were superficially similar to Near Eastern examples imported to China by Arab traders. Turquoise glazes saw further use in north China in the Chin dynasty on Tzhu-chou-style wares. In the +14th century in south China, low-fired turquoise alkaline glazes were applied to a few high-fired porcelains that were then enhanced with cold gilding to create a style reminiscent of +14th-century Near Eastern lustre wares. Aubergine, purple and inky-blue alkaline glazes soon joined the turquoise glaze in the alkaline-glaze palette in both north and south China.[460] These saw spectacular use in Chinese *fa-hua* 琺華 wares where the alkaline glaze-colours were used to 'colour in' designs created with trailed slip to create ceramics with a broad resemblance to metal *cloisonné* ware.

But perhaps most celebrated of all Chinese glazes were the high-temperature monochromes used on both stonewares and porcelains in the Sung dynasties. These glazes were often applied to exceptional thickness, and they combined unusual technical qualities (such as an extreme hardness of surface) with a remarkable subtlety of colour and texture. Their visual depths and tactile qualities became possible through the exploitation of lime-alkali glazes and slightly underfired aluminous lime glazes. These glazes were too viscous to run at the temperatures to which they were fired, so they could be applied to substantial thicknesses. This same viscosity also encouraged complex microstructures to develop within the glazes during firing and cooling. The resonance of those high-temperature effects with many aspects of the natural world, was celebrated in such Chinese descriptions as the whiteness of the moon (some Chün wares), the surface of snow (some Hsing and early Te-hua wares), and the quality of jade. Parallels with jade are the most frequent of all analogies in Chinese writing on glazes.

Sung dynasty monochrome glazes represent one aspect of Chinese taste, but a fondness for distinctive and pure colour is also an enduring Chinese trait. The latter has inspired its own glaze tradition, together with a descriptive vocabulary that often shows a strong culinary flavour. Traditional Chinese names for such glazes include 'chicken red' (*chi hung* 雞紅) and 'pomegranate red' (*shih-liu hung* 石榴紅) for copper-red wares, 'cucumber green' (*huang-kua lü* 黃瓜綠) for Han lead-glazed wares, 'spring onion green' (*tshung chhing* 蔥青) for Shih-wan stonewares, 'eelskin yellow' (*shan phi huang* 鱔皮黃) for a type of northern blackware and 'millet colour' (*mi se* 米色) for oxidised Kuan wares. To these accounts of colour can be added various evocations of quality and texture as the word *yu* 油 (oil) to describe Ching-te-chen porcelain glazes, 'mutton fat' (*yang chih* 羊脂) for Lung-chhüan celadons, 'pork-grease white' (*chu-yu pai* 豬油白) for Te-hua glazes, and 'egg white'

[459] Newton (1958), pp. 13–14.
[460] Wood *et al.* (1989), pp. 172–82.

(*luan-pai* 卵白) and 'sweet white' (*thien-pai* 甜白) for certain styles of +14th- and +15th-century Ching-te-chen porcelain glazes.

Comparisons of various Chinese glazes with gold, silver, bronze, lacquer and ivory are also abundant in the literature and, in some cases, a single glaze has inspired a veritable thesaurus of names. See, for example, the names inspired by the early +18th-century copper-red monochrome that is known in the West as the 'peach-bloom' glaze, that are mentioned on pp. 568–9.

In many cases these vivid and poetic descriptions represented attempts to find everyday analogies to glaze qualities that had evolved over the centuries. Hindsight suggests that, in most cases, Chinese potters were not actively seeking these 'natural' effects: they were largely spontaneous and had occurred through a direct use of local materials in high-temperature firings. Of course, once noted and admired, such parallels helped to define and to market the wares and well may well have been maximised by the potters where possible. However, the glazes themselves sprang from the application of some well-established Chinese approaches to glaze-construction, and these approaches were essentially practical rather than consciously imitative.

Nonetheless, there was a period in the history of Chinese glazes during the +18th century when exotic effects were actively sought, and often achieved, through a deliberate and organised programme of research and experiment, with both familiar and unfamiliar glaze materials. The Yung-Cheng reign period saw the establishment of a true experimental glaze laboratory at Ching-te-chen where very convincing ceramic copies of carved lacquer, burnished bronze and rare hardstones were made, as well as some effective reinterpretations of earlier wares, particularly high-temperature monochrome glazes of earlier, classic styles.[461]

It can be seen that Chinese glazes are characterised by a manufacturing history of some 3,500 years; the use of both low- and high-temperature firings; an enormous range of colours, qualities and textures; and a wealth of applications. The latter included ritual, burial, imperial, decorative and utilitarian uses. In many cases the celebrated qualities of Chinese glazes were fortuitous by-products of high-temperature reactions between the glaze materials, but there is also a minor tradition in China for innovation and experiment to achieve new and exotic effects.

[461] See Kerr (1993), pp. 150–64.

PART 6: PIGMENTS, ENAMELS AND GILDING

COLD-PAINTED PIGMENTS: GLASS

The urge to decorate important ceremonial and burial ceramics was felt by peoples in many societies. Later and more sophisticated potters could manufacture brightly coloured and in- or underglaze-painted glazes. In early times, however, and at simple kilns, a more straightforward method was to burnish the surface of fired pottery, and/or to decorate it with coloured slip-painting. Naturally occurring earth and mineral pigments were processed to make vibrant shades of black, white, brownish-red, ochre-yellow and green,[1] and the palette was expanded as more complex processes of pigment production were developed.

In Neolithic China, the northern loess-lands were home to several pottery-producing peoples who decorated their fired ceramics with lively painted patterns. Such wares were commonly painted with red, maroon, brown and black, these colours deriving from mineral pigments rich in iron and/or manganese compounds (see p. 5), while white was also used on some wares. The bold patterns may have been simply decorative, they may have represented beliefs and ideas, or they may have encapsulated auspicious and protective powers. As the decorators who drew such designs lived in the pre-historic period, when no written records were produced to chronicle their beliefs, such questions must remain speculative.

The painted pottery of just one Neolithic culture, the Yang-shao 仰韶, will be mentioned here, for some limited analysis has been carried out on the composition of its pigments. Fine artefacts from the Yang-shao site of Pan-pho 半坡 in Shensi province had a burnished red body and decoration carried out in iron red (from ferric oxide), white (possibly derived from amorphous bauxite[2]) and black manganese dioxide pigments.

The painted wares of Neolithic China constituted a class of luxury objects, having high status (see pp. 3–7) With the coming of the Bronze Age, the employment of pots as ritual vessels declined, and ritual ceramics were largely replaced by other materials such as bronze. The association of pigments with ceramics virtually ceased until the late Bronze Age, when two new traditions gathered pace. The first was the enlargement of the palette of colours employed to decorate the surfaces of

[1] The late Neolithic Lung-shan culture 龍山文化 at Thao-ssu 陶寺 in Shansi province (*c.* –2,500 to –2,000) has yielded earthenware and wooden vessels decorated in this palette, in which the green is unusual. See Yang Xiaoneng (1999), pp. 106–14.

[2] Research on ceramics from the Yang-shao site of Pan-tshun 班村 showed that the white derived from amorphous bauxite rather then gypsum, kaolin or other previously suggested sources. See Wang Changsui *et al.* (1995).

both burial vessels and figurines. The second was the use of pigments to colour glass, a technology having close links with the development of fired enamels.

During the Warring States period in north China, widespread use was made of two new synthetic paint pigments, both based on fused copper-barium-silicate mixtures. These have been named 'Chinese Blue' and 'Chinese Purple' and they are the tetrasilicate and disilicate respectively of barium and copper.[3] Chinese Blue has the formula $BaCuSi_4O_{10}$ ($BaO \cdot CuO \cdot 4SiO_2$), while Chinese Purple is $BaCuSi_2O_5$ ($BaO \cdot CuO \cdot 2SiO_2$).[4] Their names distinguish them from a rather similar synthetic coloured compound developed in Egypt in the -3^{rd} millennium, and known as 'Egyptian Blue'. Egyptian Blue is the tetrasilicate of copper and calcia with the formula $CaCuSi_4O_{10}$ ($CaO \cdot CuO \cdot 4SiO_2$). Egyptian Blue was used both as a paint pigment and as a bright blue material that could be moulded into objects, some of which appear superficially similar to Egyptian faience, and with which the material is sometimes confused.[5]

A number of examples of Chinese Blue and Chinese Purple pigments, dating from the Warring States and Han periods, have been analysed qualitatively. One source is a group of small (6–8 centimetres long) sticks with octagonal cross-sections, perhaps colour-sticks for use with ink stones. Analysis shows that they contain some lead oxide as an extra element, but otherwise represent mixtures of relatively pure compounds. They appear to have been given a prolonged heat treatment (>900°C) to develop the two synthetic copper barium silicates, with Chinese Blue dominating in some sticks and Chinese Purple in others.[6] The tetrasilicate is the more stable, and the rather cold blue that it provides is familiar as an unfired pigment on much north Chinese Western Han dynasty tomb pottery. Similar colours (although at present unconfirmed by analysis) appear on Chinese burial wares until well into the Thang dynasty.

The purple is the more soluble of the two compounds and usually appears now as a pale lilac or even white. Chinese Purple has been identified in pigments present in the paints used to embellish the terra-cotta warriors at Lin-thung 臨潼, Shensi province, where the pigment-particles were bonded with thin glue.[7] This distinctive pale lilac colour, formerly known as 'Han Purple' because it occurred on Han painted earthenwares, can thus be shown to have been used at least as early as the Chhin dynasty.

[3] Robert Brill seems to have been among the first to use these terms, and refers to 'Chinese Blue' and 'Chinese Purple' when discussing their relationship to Egyptian Blue. See Brill, Tong & Dohrenwend (1991), p. 36.

[4] 'Chinese Blue' has been identified in nature in the Kalahari Manganese Field in South Africa, and named 'Effenbergerite'. See Giester & Rieck (1994), p. 664. However, there is good reason to believe that Chinese Blue and Chinese Purple pigments were prepared artificially.

[5] Tite *et al.* (1987), pp. 39–41.

[6] FitzHugh & Zycherman (1983), pp. 15–23, and FitzHugh & Zycherman (1992), pp. 145–54.

[7] Thieme *et al.* (1995), p. 596. The authors note that lacquer tends to destroy the Chinese Blue and Purple colours, so paints made from these pigments probably used non-lacquer media; other pigments on the warriors were lacquer-bonded.

Some detailed recent studies of these pigments have demonstrated that there are in fact *four* possible stoichiometric ternary phases in the system BaO-CuO-SiO_2: Chinese Blue ($BaCuSi_4O_{10}$), Chinese Purple ($BaCuSi_2O_6$), a light blue ($Ba_2CuSi_2O_7$) and $BaCu_2Si_2O_7$ (also blue). It is likely that the prepared pigment-sticks often contained mixtures of these compounds.[8]

Berke and Wiedemann point out that preparation of these pigments is even today:[9]

> a rather complicated craft even for skilled contemporary chemists . . . it is obvious that such accomplishments required an extended and solid empirical foundation and a very high level of technical skill.

Barium sulphate appears to have been the most likely source of barium for preparing these colours.[10] This differs from Chinese glass, where barium carbonate has been suggested as the prime source of barium oxide.[11] Nonetheless, one example of Chinese Blue examined did contain some residues of barium carbonate. Berke and Wiedemann also found that lead salts (lead carbonates or oxides) were essential if barite ($BaSO_3$) were used to create Chinese Blue and Chinese Purple, both to promote the decomposition of barite, and also to act as a general flux to bond the particles of pigment during firing.

In order to generate the colours from the initial raw materials (quartz, barite and lead and copper compounds) the kiln temperatures needed to be kept within 50°C of 1,000°C for some twenty hours. In terms of firing control, Chinese Purple was the more demanding, as the mineral disappears if it becomes too hot and begins to melt, unlike Chinese Blue, which retains its colour even when allowed to fuse completely.[12] Both pigments develop their most intense colours on grinding.[13]

As to the origins of this complex and demanding aspect of pyrotechnology, Berke and Wiedemann speculate that knowledge of Egyptian Blue manufacture may have been transmitted to China via the route that 'later became known as the Silk Road', or that actual trade in Egyptian Blue may have provoked interest in making a local alternative in China.[14] However neither suggestion explains how the radical step of substituting barium for calcium compounds in the preparation of the colours came to be taken.

An alternative path for these colours might be from glass- or glaze-making, but this in turn raises the key question of the relative precedence of barium-based pigments, barium-containing glasses, and barium-containing glazes in China. Any of these materials could have led to the manufacture of the other two, simply by varying

[8] Berke & Wiedemann (2000), p. 102.
[9] *Ibid.*, p. 97.
[10] *Ibid.*, p. 99.
[11] Brill (1990), p. 35.
[12] Berke & Wiedemann (2000), p. 114.
[13] *Ibid.*, p. 111.
[14] *Ibid.*, p. 117.



Fig. 148 Warriors in the burial tumulus of Shih-Huang-Ti, First Emperor of the Chhin 秦始皇帝, their faces showing traces of darkened and damaged pigments

the typical constituent ingredients. But even if such precedence can be convincingly established, the origin of the first material in the series (be it glass, glaze or pigment) must then be considered.

Paints on the Terra-cotta Warriors

As mentioned, a notable use of Chinese Purple occurred on the terra-cotta warriors. Originally, like much early Chinese sculpture, the figures were painted in bright, life-like paints that added to their realism and thus their efficacy as protective burial guardians. This coloured painting has now mostly darkened, weathered away, or transferred to the surrounding loess.

The warriors were fired initially to temperatures in the range 800–1,000°C, and this supplied a porosity of about 30% to the ceramics so the figures' surfaces were sealed with two layers of 'undercoat' before the various paints, coloured with both organic and mineral pigments, and variously bonded with thin lacquer or glue, were applied.[15]

The dominant colours in the top layer were red, green and black, but purple, pink, blue and violet paints were used for details. Although the use of organic pigments is suspected for some of the more fugitive colours, their exact chemistries

[15] Thieme *et al.* (1995), pp. 596–7.

Table 122 *Mineral pigments identified in the paints used on the terra-cotta warriors and horses*[a]

No. of Samples	Pit 1	Apatite (bone ash)	Azurite	Cerussite	Cinnabar	Malachite	Chinese Purple	Minium
	Colour	$(Ca_5(PO_4)_3OH$ (white)	$Cu_3(CO_3)_2(OH)_2$ (blue)	$PbCO_3$ (white)	HgS (red)	$Cu_2CO_3(OH)_2$ (green)	$BaCuSi_2O_6$ (purple)	Pb_3O_4 (orange)
3	pink	3		1	3			
1	red	1			1			
1	purple				1		1	
	Pit 3							
3	pink	3		1	1			
3	red				3			
1	blue		1			1		
2	green		1			1		
1	ground			1	1			1

[a] From Herm *et al.* (1995), p. 679, table 2.

cannot now be identified. However, a wealth of mineral pigments show up well in analysis (see Table 122) and Herm *et al.* decided from study of the medium employed that:[16]

> it can be assumed that the original samples represent a mixture of lacquer with some other carbohydrate binding medium (for example, starch or gums).

The Development of Colours in Glass

We have described on pp. 474–80 an important development in Chinese glaze history, namely the manufacture of ash-paste beads, starting in the Warring States period. All the glaze-colours used on the beads were achieved in ways distinct from the imported Near Eastern originals. The white was opacified by undissolved quartz and albite; the red was overloaded with hematite crystals (Fe_2O_3) which gave an opaque reddish-brown colour to the glaze; and the yellow glaze was coloured by ferric oxide, largely in solution (Fe^{3+} ions) and opacified by microcrystals of the barium feldspar celsian that had formed during firing.[17] The sources of the blue colour proved to be copper, much of it present in the form of Chinese Blue. It was not possible to tell whether the intensely blue copper-barium tetrasilicate had formed during firing, or whether it had been introduced to the glaze-batch as a pre-fired ceramic pigment.

In terms of composition, the white and blue glazes appear to have been made from mixtures of quartz, albite and orthoclase, combined with lead and barium ores. The former minerals might have been supplied by a quartz-feldspar rock. The red-brown glaze used ground quartz mixed with lead-barium ores and about 18% of ground hematite, while the yellow glaze appears to have been made by combining a fusible and ferruginous clay with lead-barium ores in about equal proportions.[18]

These glazes represent a number of 'firsts' in Chinese ceramics: they are the earliest earthenware glazes so far discovered; the first known polychrome glazes; the first iron-red glazes found; and the first glazes shown to have been coloured with a copper-barium silicate. Their compositions appear to be an entirely Chinese response to imported Western eye-beads, that had been decorated variously with calcium-antimonite white, copper-red, lead-antimonite yellow, cobalt-blue and copper-blue soda-lime glasses.

Of the four small Warring States period vessels whose inlaid decorative colours relate to eye-beads (see pp. 480–2), one has been analysed. The lidless example in the British Museum, although the most weathered with a chalky surface, whose main glaze-colours are now reduced to browns and white, has been studied in depth. It was examined qualitatively in +1995, and shown once to have been

[16] *Ibid.*, p. 678.
[17] Wood *et al.* (1999), p. 29.
[18] *Ibid.*, pp. 32–3.

decorated with red, yellow and blue lead-baria glazes coloured variously with iron and copper.[19] Chinese Blue was identified in some remains of the blue areas, although, as with the blue bead glaze, it was not possible to say whether the mineral was a product of the firing, or whether it had been prepared separately and then added to the raw glaze-batch. Apart from its body, the jar proved to be a very close relation to the glazed bead, and the ash-paste bead provides a good image of how these now-weathered glazes would have seemed when newly fired.

While the faience beads tend to be dated somewhat earlier than most Chinese glasses, the true antiquity of the copper-barium silicate pigments still have to be assessed, and the dating of the four glazed pottery jars still remains somewhat arbitrary.

THE DEVELOPMENT OF FIRED ENAMELS

Glass and glaze technology are closely related, and we have followed the evolution of lead glazing in Part 5 of this book. That branch of Chinese ceramic history may well have grown from glass and glazed-bead technology, and it flourished particularly in the Han and Thang dynasties.

The next significant development involved the use of fired enamels applied to glazes, and it greatly enlarged the decorative repertoire. The monochrome-glaze principle, with its largely fortuitous invocations of prestige materials such as greenish-white jade and black or brown lacquer, was a dominant theme in Chinese high-fired ceramics of the +10th to +12th centuries. By the +12th to +13th centuries more figurative designs and a much greater use of colour began to gain ground in the north. Indeed one of the great differences between northern and southern kiln-complexes in this period was the tendency for northern kiln sites to manufacture a wide range of wares, many of them highly decorated, while most southern kilns concentrated on single ceramic types, and mainly of monochrome style, such as *chhing-pai* 青白 porcelain, or some form of greenware, or blackware. Many southern kilns operated the ceramic equivalent of monoculture, with their mass-produced wares appearing impressive, if somewhat monotonous. This can be compared with the 'mixed farming' practised in the north, where wares from a single kiln-complex can be quite startling in their variety and range. The kilns of Kuan-thai 觀台 in southern Hopei province typify this northern approach and were especially diverse in their manufacture, making greenwares, Chün wares, blackwares, black-and-white wares, whitewares, and coloured lead-glazed wares, together with numerous sub-types within this range (see also pp. 170–5).

A particularly interesting combination of the Tzhu-chou principle with low-firing glazes occurs with Kuan-thai overglaze enamelled wares. In this pioneering overglaze technology low-firing red, yellow and green lead glazes were applied to already fired white-slipped stonewares, and then given quick firings to *c.* 800°C to

[19] Wood & Freestone (1995), p. 15.

mature the enamels, and to develop some bond with the transparent stoneware glazes beneath. The coloured glazes were painted in a broad and lively style reminiscent of slip-painted Tzhu-chou wares 磁州窯. The semi-opaque red glaze was used for the structures of the patterns, and the yellow and green glazes for their details. Some kilns making enamelled Tzhu-chou wares (including the Kuan-thai complex) had already produced glazed stonewares with overall green lead glazes, applied in a final low-temperature firing, and these can be regarded as early monochrome versions of the polychrome overglaze enamel principle.[20]

Overglaze enamels seem first to have appeared at Kuan-thai in the period *c.* +1148–1219, i.e. the mid-late Chin dynasty.[21] But polychrome Tzhu-chou type wares with overglaze decoration were also made at a group of about twenty kilns in Hopei, Honan, Shansi and Shantung provinces. They date to the mid-late Chin period, as pieces with attributable dates make clear. They were produced until the early Ming dynasty and then disappeared, probably as a result of the market being taken over by Ching-te-chen 景德鎮.[22]

New though the overglaze enamel technique was in the late +12th century, the lead-based colours adapted for Tzhu-chou enamelled wares had some antiquity in China. The yellow came from a small amount of ferric (iron III) oxide in solution (Fe^{3+} ions), the red from ferric oxide in excess in the glaze, and therefore largely in suspension, and the green from copper (II) oxide in solution (Cu^{2+}). All three colours used low-firing lead-rich bases.

The use of low-firing yellow, red and green glazes can all be traced in China to the later Warring States period. Then they were applied as polychrome glazes to ash-paste beads (described above and on pp. 474–80), albeit in lead-oxide+baria, rather than simply lead-oxide, fluxed matrices.[23] The Tzhu-chou iron-red therefore appears more of a revival than the green and the yellow enamels, as these had enjoyed some continuity in lead-glaze production since the –3rd century. Comparisons of lead-baria bead glazes from the Warring States period with Chin overglaze enamels show both the similarities and the differences that exist between these two low-temperature Chinese polychrome-glaze traditions (Table 123).

As discussed on p. 614, the Warring States glaze that contained copper fired blue rather than green, and derived its colour from a copper-barium-silicate, i.e. effenbergerite or 'Chinese Blue'. This colour had disappeared from the Chinese ceramic glaze repertoire by the Western Han dynasty, although its use continued as a paint pigment for some time after. Nonetheless, translucent green Warring States bead glazes apparently coloured by Cu^{2+} ions also exist, but have not so far been analysed. These transparent green bead glazes may well be the ultimate ancestors of the Tzhu-chou green enamels.

[20] Scott *et al.* (1995), p. 155.
[21] Chhin Ta-Shu (1997), p. 86.
[22] Chhin Ta-Shu & Ma Chung-Li (1997), pp. 61–3.
[23] The red and yellow glazes have been analysed in Wood *et al.* (1999), p. 31, but the green examples seen on some Warring States glazed beads have not so far been studied analytically.

Table 123 *Warring States bead glazes compared with Chin dynasty Tzhu-chou enamels*

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	BaO	PbO	P_2O_5	CuO	Total
Red bead glaze[a]	42.3	2.0	<0.1	17.8	<0.1	0.4	2.0	1.1	0.7	8.9	24.2	<0.1	<0.1	99.4
Yellow bead glaze	27.0	8.6	0.4	4.7	<0.1	0.7	1.5	0.8	0.7	20.1	35.0	<0.1	<0.1	99.5
Blue glass matrix	49.9	4.4	0.9	0.5	0.1	0.4	0.85	2.2	1.2	14.8	21.9	<0.1	2.4	99.6
Green Tzhu-chou enamel[b]	24.5	3.2	0.06	0.2	-.-	0.2	0.9	0.4	0.25	-.-	65.9		3.5	99.1
Yellow Tzhu-chou enamel[c]	24.0	5.25	0.1	4.6	-.-	0.6	2.1	0.9	0.8	-.-	61.5	-.-	0.08	99.9
Red Tzhu-chou enamel[d]	52.0	11.5	0.1	8.0	-.-	0.9	3.5	0.6	2.5	-.-	20.0		0.04	99.1

[a] Warring States bead analyses from Wood *et al.* (1999), p. 31, table 2.
[b] Kingery & Vandiver (1986a), p. 365, table 1.
[c] Vandiver *et al.* (1997), p. 28, table II.
[d] Kingery & Vandiver (1986a), p. 365, table 1.

The essential compositional principles for these enamel glazes were therefore some 1,500 years old in China, but the concept of overglaze enamels applied to high-temperature glazes was a novelty in ceramic history. Its earliest use in China tends to be placed to the late +12th century, largely because two early examples bear a date in ink equivalent to +1201.[24] Strictly speaking, the use of polychrome lead glazes on a stoneware ground had occurred considerably earlier in north China. The method has been identified on some *san-tshai* 三彩 export wares, found in the Near East, and probably made at Kung-hsien in the late Thang dynasty.[25] However, the application of some *san-tshai* glazes to *unglazed* pre-fired stoneware makes the Thang dynasty technique a forerunner to polychrome enamels-on-biscuit,[26] rather than to polychrome enamels-on-glaze.

CHINESE AND PERSIAN OVERGLAZE ENAMELS

Persian overglaze enamels seem to have appeared somewhat earlier than their Chinese counterparts (the late +12th century),[27] and West Asian enamelling on glass can be dated to at least the +1st century.[28] In practice, Near Eastern and Chinese enamelling on ceramics were rather different in their approaches: Persian *mina'i* wares show far more detail in their execution, and resemble ceramic versions of Persian miniature painting. Persian enamellers on ceramics also used a wider palette and made greater use of semi-opaque compositions, including an iron-red and a chromite-black.[29] In Persia the various enamel colours were painted on to fired tin-opacified white (and occasionally blue) earthenware glazes. The bodies were stone-paste materials and fired to earthenware temperatures. These white siliceous 'pastes' were made largely from quartz, with small additions of clay and glass, and had been evolved initially to copy imported south Chinese porcelains, probably in the +12th century.[30] Maturing temperatures for *mina'i* enamels were therefore much closer to the earthenware glazes beneath, and many

[24] Mino (1998), pp. 314–19, divides these wares into three types: those with red outlines, filled in with yellow, red and green; those using stylised floral motifs without outlines; and those decorated predominantly with Chinese characters. Mino suggests that the earliest type is those which are: 'first outlined in red and then filled in with the red green and yellow enamels. Three pieces, two of which are dated by ink inscriptions on the unglazed base to the year 1201, are probably among the earliest of this type.' *Ibid.*, p. 315. The examples dated to +1201 are in the Tokyo National Museum and The Art Institute of Chicago.

[25] Rawson *et al.* (1989).

[26] Called *su-san-tshai* 素三彩 in Chinese, see p. 362.

[27] One early Persian overglaze enamelled bowl from Kashan is dated to AH 576 (+1180). See Abd el-Ra'uf Ali Yousuf (1998), p. 20. Mason *et al.* (2001), give a detailed account of the technology of Persian *mina'i* wares and see the origins of the technique in attempts to emulate Syrian polychrome wares. This difficult and rare process: 'was only short-lived, its use apparently being mainly confined to the last half of the 12th century AD, and possibly to a more restricted time within that span.' Mason *et al.* (2001), pp. 207–8.

[28] Rütti (1991), p. 123, writes: 'It may be assumed that the Levant was . . . the origin of enamelled glass. By the end of the first century BC and the beginning of the first century AD, the period in question for the earliest specimens of enamelled glass, Levantine factories on the Syrian coast and in Egypt had brought the art of glass-making to perfection.'

[29] Mason *et al.* (2001), p. 204.

[30] See Mason & Tite (1994b), for a survey of Islamic stone-paste technology. The subject is explored on pp. 735–9 of this volume.

of these 'enamels' were lightly fluxed pigments rather than true glazes.[31] The Chinese method, by contrast, showed a much broader style of painting and combined the toughness of high-fired stoneware with the brilliance and rich colour-potential of low-firing lead glazes.

Overglaze Enamels at Ching-te-chen in the Yuan to Chhing Dynasties

Many innovations in overglaze enamelling were made at Ching-te-chen from the Yuan dynasty onwards. The technique had spread from the northern Tzhu-chou kilns to south China in the later +14th century, and was developed at Ching-te-chen in the +15th century for application to the best Ching-te-chen wares.[32] Dedicated technicians experimented in workshops there, with colour materials allocated by government from national warehouses in Chiangsi province. There was a special Ornamentation Service (*Yen-liao Chü* 顏料局)in the Ministry of Works, headed by a Commissioner-in-chief (*Ta-shih* 大師).[33] Initiatives continued during the early Ming period. For example, *tou-tshai* 斗彩 ('dovetailing colours') first appeared on imperial wares in the Hsüan-Te reign period. They constitute an extremely refined style of overglaze decoration, in which underglaze-blue outlines were first drawn and fired on to porcelain, and overglaze colours were subsequently painted within the outlines and fixed in a second, lower-temperature firing. When the style first appeared in the Ming it was simply known as another form of *wu-tshai* 五彩 ('five coloured' or polychrome). The term *tou-tshai* first appeared in the +18th-century miscellany *Nan Yao Pi Chi* (Notes on Southern Kilns, *c.* +1730–40).[34] Their enamel compositions seem related to those used on the Tzhu-chou enamelled stonewares of north China, but superior raw materials and exceptionally white porcelain grounds imbued the enamel-colours with a particular jewel-like brilliance. The almost legendary value of Ming dynasty *tou-tshai* wares has meant that few fully quantitative analyses have been attempted of these +15th-century overglaze enamel compositions, and the following are the only examples available at the time of writing (Table 124).

[31] Mason *et al.* (2001), p. 207, estimate 890° to 920°C for: 'both the paints and glazes of mina'i wares.' The greater fusibility of the glazes used beneath early Persian overglaze enamels, compared with the high-fired glazes on Chinese examples, may make it difficult to decide which of the colours used in the decoration of the Persian wares are actually overglaze enamels fired at lower temperatures, and which were used in the initial, higher, glaze-firing. Oliver Watson (1988), p. 17, goes so far as to say of early Persian ceramic enamels that: 'The enamel colours normally are only red and black . . . In more elaborate pieces a greater range of enamel colours is used, though the blue green and purple tend always to be in-glaze rather than overglaze colours, and leaf gilding may be applied.'

[32] Scott *et al.* (1995), pp. 156–8.

[33] *Chiangsi Sheng Ta Chih*, ch. 7, pp. 11b–13a; *Ta Ming Hui Tien*, ch. 193, p. 1; Hucker (1985), p. 579.

[34] *Nan Yao Pi Chi*, p. 319/5a; see Liu Hsin-Yüan (1993), pp. 36–7, 75–9.

Table 124 *Chheng-Hua period* tou-tshai *and later +15th-century Ching-te-chen overglaze enamels*[a]

	PbO	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	CuO	CoO	Cl	Total
Green enamel	51.8	36.7	5.4	0.0	1.1	0.1	0.3	2.6	-.-	0.8	1.3	-.-	0.0	100.1
Purple enamel	60.4	30.9	3.9	0.0	1.0	0.7	0.3	1.6	0.7	0.5	0.1	0.2	0.0	100.3
Eutectic mixture	61.0	31.7	7.1				(melts	650°C.)						
Body for above	0.2	63.0	28.0	0.07	1.00	0.1	0.7	1.0	1.5	3.7	0.01	0.0	0.2	99.5
Glaze for above	0.05	69.6	17.5	0.1	1.4	0.1	0.8	4.8	1.5	4.2	0.0	0.0	0.0	100.1

[a] Vandiver *et al.* (1997), p. 28, table II.

Table 125 *Ching-te-chen overglaze enamels and their porcelain glaze: 2nd half of the +15th century*[a]

	PbO	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	CuO	CoO	Cl	Total
Green	50.9	34.2	5.1	0.0	0.4	0.04	0.5	1.1	1.3	2.2	1.6	0.0	2.7	100.0
Yellow	54.8	31.6	3.9	0.0	2.3	0.0	0.35	0.6	1.6	1.8	0.05	0.0	3.1	100.1
Red	43.3	30.1	6.1	0.1	13.9	0.04	0.6	2.5	1.7	1.6	0.03	0.0	0.0	100.0
Porcelain glaze	0.01	71.0	16.7	0.0	0.9	0.06	0.7	2.5	1.9	6.1	0.0	0.0	0.0	99.9

[a] Vandiver *et al.* (1997), p. 28, table II.

Two significant innovations appear in these analyses. The first concerns enamel colour and the second the porcelain body beneath. With regard to the enamels, one analysis shows the use of a manganese-cobalt ore to produce purple. That effect may have resulted, initially, from unsuccessful attempts to make a low-firing overglaze enamel-blues from the manganese-rich cobalt ores used for underglaze painting.[35]

The second innovation concerns the high-alumina nature of the *tou-tshai* bowl, which has a body composition more typical of manufacture at Ching-te-chen during the late Ming to early Chhing dynasty, than of +15th-century production. Its paste is richer in kaolin than any +15th-century Ching-te-chen porcelain thus far studied. It may be that special high-kaolin recipes were developed in the +15th century for *tou-tshai* wares, with the high levels of platy materials contributing to the fineness and smoothness of the pastes. A second suite of analyses of +15th-century (non-*tou-tshai*) Ching-te-chen overglaze enamels, and their associated porcelain glaze, are published in the same paper, and were applied to a jar dated to the second half of the +15th century (Table 125).

Unusual levels of sodium oxide and chlorine occur in these later +15th-century yellow and green enamel compositions. Although not discussed by the paper's authors, these high Na_2O+Cl levels may reflect some use of common salt (NaCl) in the enamel recipes studied.[36] It is also noticeable that the amount of ferric oxide in the red enamel has risen from 8% in the Chin dynasty Tzhu-chou red, to about 14% in the Ming example. This trend seems to have continued into the Chhing dynasty, when ferric (iron III) oxide levels in Ching-te-chen enamels reached *c.* 23% Fe_2O_3.[37]

Pamela Vandiver and her co-authors propose that the yellow and green enamels, used on both the Chin dynasty Tzhu-chou ware example, and the +15th-century Ching-te-chen porcelain piece, were fritted (that is pre-melted and then ground) before use. The reds would not have been fritted as this would have dissolved too much ferric oxide and spoiled their colours. The authors also suggest that fritting had already been practised in China with some lead glazes applied to Thang and Chin dynasty lead-glazed earthenwares.[38] Fritting can be useful with overglaze enamels, and the technique is widely practised in the West. Fritted enamels are

[35] Wood, in Henderson *et al.* (1989b), p. 322.

[36] Although the sodium oxide level in the red enamel is nearly as high as that found in the yellow and green enamels, the red enamel is entirely lacking in chlorine. Nonetheless the volatility of Cl may have caused its loss from the thin and semi-fused red enamel during the enamel firing. As Vandiver *et al.* (1997), p. 33, write: 'the reds are opaque, porous (about 20 vol. %) and have a rough sintered quality. . .', an ideal structure for the loss of volatiles.

[37] Kingery & Vandiver (1986a), p. 370, table 11.

[38] Vandiver *et al.* (1997), p. 29, write of the Chin dynasty enamels: 'it is highly likely that the yellow and green overglaze enamels were each compounded separately, heated until a glass formed, then cooled, crushed, ground – a process known as fritting – and then applied in a suitable medium as a liquid paint.' In summary (discussing both the Chin and the +15th-century Ching-te-chen enamels) the authors write that 'each colour was individually fritted for the yellows and greens.' *Ibid.*, p. 32.

more homogenous in their compositions, and their maturation in the kiln proceeds more rapidly than with unfritted recipes.

If fritting had been used for early Ching-te-chen overglaze enamels, the practice seems to have died out by the early +18th century, when Père d'Entrecolles described simple mixtures of white lead, quartz, and oxide colourants for the making of Khang-Hsi period enamels.[39] For the late +19th century, Georges Vogt describes similar mixtures of raw lead and silica for some lead-fluxed monochrome glazes made at Ching-te-chen, basing his study on recipes and samples collected in Ching-te-chen by Scherzer in November +1882. Vogt remarks:

> The simplicity with which the Chinese prepare their enamels for fluxing is truly remarkable; they only mix the primary materials, and without giving them any preliminary vitrification they use them to decorate their porcelain.

One Kuang-Hsü period low-fired yellow glaze analysed by Vogt can be compared with the Hsüan-Te period monochrome yellow example studied in Vandiver *et al.*'s paper (Table 126).

Georges Vogt describes the glaze on the late +19th-century piece, which was intended for the 'semi-high fire', as confirming a recipe supplied by Scherzer. Materials were not pre-fritted, but were simply mixed in the proportions: 75% white lead, 5% red ochre and 20% quartz sand. This recipe can be compared with a typical overglaze enamel recipe from d'Entrecolles, i.e. an overglaze-yellow made from 74.7% white lead, 24.6% quartz and 0.6% ferric oxide, again all unfritted.[40]

Using lead-fluxed glazes in an unfritted state is relatively straightforward. The raw materials are insoluble and firing times simply have to be extended somewhat to allow the enamel-ingredients to interact and to melt smoothly.[41] What is perhaps more remarkable is Vogt's discovery that Ching-te-chen potters were also able to make true *alkaline* low-firing glazes, fluxed with the semi-soluble material saltpetre (potassium nitrate KNO_3), that could be used entirely in an unfritted state:[42]

> nothing in its composition needs to be melted, or to be fritted, the only preparation needed is to grind together the saltpetre the quartz and the copper powder in suitable proportions and it is ready to be used on porcelain vases.

CHING-TE-CHEN TURQUOISE-BLUE ALKALINE GLAZES

By the time Vogt analysed this sample in the late +19th century, low-temperature turquoise-blue glazes had already seen more than 500 years production at Ching-te-chen. This long continuity is evident in the analysis of a low-temperature Hsüan-Te period copper-turquoise-blue, also from Vandiver *et al.*'s +1997 paper, and shown in Table 127. Low-temperature turquoise-blue glazes had also been used

[39] Tichane (1983), p. 81, translation of Père d'Entrecolles' letter of +1712, describes a 2:1 mixture of powdered calcined quartz mixed with white lead as a typical Khang-Hsi overglaze enamel-base at Ching-te-chen.
[40] Tichane (1983), p. 122, translation of d'Entrecolles letter of +1722.
[41] Personal experience of one of the authors (NW).
[42] Vogt translated by Tichane (1983), p. 293.

Table 126 *Ching-te-chen overglaze-yellow enamels and its porcelain glaze: 2nd half of the +15th century*[a]

	PbO	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	CuO	Cl	Total
Hsüan-Te monochrome yellow	65.7	27.6	1.3	0.0	4.1	0.0	0.1	0.3	0.5	0.3	0.01	0.0	99.9
+1882 monochrome yellow	73.5	21.4	1.5	-.-	3.1	-.-	trace	0.1	0.2	0.2	-.-	-.-	100.0

[a] Vandiver *et al.* (1997), p. 28, table II; Vogt (1900), p. 600 (normalised from this analysis).

Table 127 *Turquoise overglaze enamel of the Hsüan-Te reign period and the porcelain glaze beneath, compared with a potassia-fluxed turquoise-blue glaze analysed by Vogt*[a]

	PbO	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	CuO	CoO	Cl	SnO_2	Total
Turquoise enamel	0.3	76.9	2.8	0.0	1.2	0.02	0.25	0.3	1.6	11.0	5.7	0.0	0.0	1.3	101.4
Porcelain glaze	0.02	74.1	13.6	0.0	0.9	0.1	0.6	3.5	1.8	5.4	0.0	0.0	0.0	0.0	100.0
+1882 turquoise glaze	-.-	61.3	2.3*	-.-	-.-	-.-	0.3	0.3	0.4	26.3	9.0	-.-	-.-	-.-	97.6
+1882 body for above**	-.-	76.1	18.0	-.-	1.0	-.-	0.2	0.2	0.4	4.1	-.-	-.-	-.-	-.-	100.0

('-.-' = not analysed; '0.0' = sought but not found. * Al_2O_3 and Fe_2O_3 added together. ** Normalised from published analysis.)
[a] Vandiver *et al.* (1997), p. 28, table 2; Vogt (1900), pp. 598 and 560.

on Yuan dynasty tiles in north China,[43] and on official wares at Ching-te-chen in the mid +14th century.[44] In the larger history of Chinese ceramics, the glaze occurs as early as the +7th century on some Thang dynasty *san-tshai* wares and, exceptionally, on a Han dynasty jar from Hunan province (see pp. 464–6).[45] In glass technology the potassium-silicate technology may be earlier still, as many high-potassia glasses have been found in Western and Eastern Han tombs in China. It is possible that these potassic glasses were made 'somewhere between south China and mainland South-east Asia' rather than in China itself.[46]

The Hsüan-Te period turquoise-blue was used over an extremely white porcelain glaze, of a type used earlier at Ching-te-chen for Yung-Le period *thien-pai* 甜白 wares. Vogt's turquoise-blue, by contrast, was applied direct to the hard-porcelain biscuit body. This late +19th-century 'turquoise body', analysed by Vogt, was made from a single kaolinised quartz-mica rock, similar to the earlier, 'one material' type of Ching-te-chen *chhing-pai* ware. This highly siliceous porcelain material would have helped to improve glaze-fit with the high-expansion turquoise glaze. It is noticeable that the Hsüan-Te period white glaze too is unusually high in silica, perhaps again for reasons of expansion compatibility.

Although the Hsüan-Te period glaze and the +1882 glaze differ in details such as in their potassia and cupric oxide levels, they share the same approach to construction. Both are simple potassia-alumina silicates, coloured with copper. Vogt established that the glaze was neither melted nor fritted, and that it contained 40.83% natural saltpetre (largely potassium nitrate), 8.56% copper powder and 49.18% quartz.[47]

CHINESE POTASSIA-FLUXED GLASSES AND GLAZE

Turquoise glazes created at Ching-te-chen during both the early Ming and late Chhing dynasties, and described above, are notably higher in silica than any of the lead-fluxed glazes described in this chapter so far. This seems to be because the useable eutectic mixtures that operate within the silica-alumina-potassia system are highly siliceous in their natures. These high-silica mixtures have the virtue of remaining insoluble after firing, an essential condition for a stable glaze or glass. In fact these high-silica glassy eutectic mixtures containing potassia are very similar in their oxide-balances to some useful eutectic mixtures that occur in the sodium oxide-alumina-silica systems. As mentioned on p. 84, such mixtures provided the compositional bases for the world's first glazes, those used on Near Eastern stone-based bodies of the −5th to −4th millennium (Table 128).

[43] For example, the magnificent demon tile illustrated by Chhai Tse-Chün (1991), pl. 42, and shown in this volume as fig. 139.

[44] Liu Xinyuan (1993), p. 34 pl. 2. Yuan turquoise-glazed wares were sometimes enhanced with gilding, perhaps in imitation of Near Eastern turquoise wares bearing silver lustre, which has a golden hue, see p. 704.

[45] Wood (1999), p. 214.

[46] Glover & Henderson (1995), p. 160.

[47] Vogt (1900), p. 598, translated in Tichane (1983), pp. 292–3.

Table 128 *Eutectic mixtures in the silica-alumina-potassia and silica-alumina-soda systems*[a]

Melting-point	SiO_2	Al_2O_3	K_2O	Na_2O
Potassia-fluxed				
880°C	82.5		17.5	
870°C	77.5	5.2	17.3	
Soda-fluxed				
860°C	81.6			18.4
800°C	77.1	5.1		17.8

[a] Singer & German (1974), p. 87, appendix 5.

Despite the underlying compositional parallels between these two sets of eutectic mixtures, the fact that Chinese glaze-makers based their alkaline glazes on silica-potassia mixtures, rather than silica-soda mixtures, suggests that the technology for Chinese alkaline glazes developed independently from any West Asian technological influence. It is more likely that they derived from Indian or South-east Asian practice. This means that, while some Chinese alkaline glazes were certainly inspired by the characters and the colours of imported Near Eastern wares, their actual glaze-constituents, and with them their essential chemical constitutions, represented a very different approach to the manufacture of alkaline glazes.

The first appearance in China of faience beads with high-potassia compositions occurred well before low-firing glazes were first produced in the country, in the early Western Chou period, in Pao-chi 寶鷄 and Fu-feng 扶風縣 counties in Shensi province.[48] These quartz-rich beads bonded with high-potassia glass were discussed on p. 474. As mentioned there, some doubts still exist about the origins of the beads. A thousand years or more passed before high-potassia glasses occurred again in China, this time in the Han dynasty, and mainly in tomb excavations in the south of the country. As Zhang Fukang [Chang Fu-Khang 張福康] explains:[49]

There have been many K_2O-SiO_2 glass relics excavated from Han dynasty tombs located in Guangxi [Kuangsi], Guangdong [Kuangtung], Yunnan, Henan [Honan], Gansu [Kansu] and Jiangsu [Chiangsu] provinces. They include beads, eye-beads, pendants and cups. All are quite similar in chemical composition, the K_2O contents being 14–17%, SiO_2 71–81% and Al_2O_3 2–5%. Na_2O and CaO are usually very low . . . Natural saltpetre is considered the most probable source of potash for making glass in ancient China.

These high-potassia glasses from Han dynasty tombs have been studied and analysed in a paper published in +1987 (Table 129).[50]

[48] Brill *et al.* (1989); Brill *et al.* (1991); Shi Meiguang (1987), p. 11.
[49] Zhang Fukang (1991), pp. 160–1.
[50] Shi Meiguang *et al.* (1987), pp. 15–20.

Table 129 *Some high-potassia glasses excavated from Han dynasty tombs, plus glass from Arikamedu (Pondicherry) in India*[a]

Glass object	Locality and date	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	CuO	MnO_2	CoO	Total
GH-20 Green cup	Kuangsi, E. Han	74.9	4.2	0.6	0.03	0.15	16.0	0.2	1.2	0.01	-.-	97.3
GH-15 Dark-blue bead	Kuangsi, W. Han	74.7	3.0	1.35	0.6	0.3	15.5	0.2	-.-	1.7	0.06	97.4
GH-24 Red bead	Kuangsi, E. Han	65.9	4.1	1.1	2.15	2.8	16.0	2.5	2.4	0.22	0.0	97.2
+1st century glass from Arikamedu[b]	Arikamedu	73.8	1.8	2.3	1.15	0.3	16.5	0.3	0.03	3.0	0.07	99.3

[a] Shi Meiguang *et al.* (1987), pp. 17–18, tables 1 and 2.
[b] Brill (1999), p. 337, table XIIIE (fragment of blue cullet from Arikamedu).

The paper noted that many of the objects, such as glass ear-pendants and belt-hooks, were made in a Chinese style and that known glasses of the period made beyond China had very different compositions from these potassia-rich materials. But it cautioned that a Chinese origin for the original glass material is still not an accomplished fact:[51]

> the authors notice that according to the historical record, the 'liuli' (a glass-like material) was introduced into China from South-east Asia during the reign of 'Emperor Wudi [Wu-Ti]' (156–87 BC) of Western Han.

Glass, of course, differs from ceramics in that it is easily recycled and much glass-trade in the ancient world took the form of cullet or glass ingot, and this trade was often international and far ranging.[52] Therefore, even if these coloured glass objects were made in China, this does not mean that the original glass was produced in the country. This has some relevance to developments in Chinese silicate technology for, if these high-potassia glasses were mixed, made and fashioned within China, they would represent a new approach to glass technology in the world. In addition they would also supply examples of the first known cobalt glass made from Chinese materials, and the first known use of the copper-red effect in China. As things stand, however, these possibilities have to be borne in mind, while remaining unproven.[53]

A rare use of the low-firing turquoise glaze occurs on some more elaborate Thang dynasty *san-tshai* wares, but only in small areas, which suggests that the colour may have been expensive. No example from the Thang dynasty has been analysed to date, so we have no hints as to whether this turquoise glaze was a Chinese material, nor if it were based on glass or glaze. After these Thang dynasty experiments there seems little evidence for the use of the low-temperature turquoise colour in China until the early Chin dynasty (+12th century) when turquoise glazes were used overall on some rare northern bottles, and also as details on some Chin dynasty Tzhu-chou-ware lead-glazed pillows. The colour is more abundant in the later +12th and +13th centuries when it can appear overall as a true turquoise enamel on painted and glazed Tzhu-chou stoneware. From the +14th

[51] *Ibid.*, p. 20.

[52] A good example is Saxon glass from Jarrow in England. This was made from cullet from a glass-works in Israel, established by the Romans. Ian Freestone, pers. comm.

[53] Brill (1991), pp. 2–3, tends towards a Chinese origin for these potassia-silica glasses: 'In those areas where lead ores were scarce (for example, Guangdong [Kuangtung] and Guangxi [Kuangsi]), the glasses were K_2O-SiO_2 types (containing 15% K_2O, only rarely Na_2O and CaO). This latter glass system is believed to be unique to China because it has not been found in other countries.' An Jiao (1996), p. 131, muses on the historical references to the Emperor Wu's sending people to the 'Southern Sea' to buy glass: 'At the current level of our knowledge we do not know where was *Southern Sea* and if the glass to be bought was potassium glass. What we do know is that Arikamedu (Pondicherry, India) was a center of glass beads manufacture ca. 3rd century B.C. to 3rd century AD . . . It is very possible that the glasses found in the South of China were trade beads from India or South-east Asia, but it is only a conjecture before the Indo-Pacific glass beads and other artifacts are chemically analyzed.' Arikamedu glass has been analysed, however (see table 66), and is indeed of the high-potassia, low-magnesia type, very similar to the Chinese finds (see table 66). Whether Arikamedu glass was produced where it was used for making glass artefacts, though, is another problem.

century to the present day, low-fired high-alkali glazes represent a minor, but regular, theme in Chinese ceramic manufacture. They are often used on roof tiles and on other architectural ceramics, and usually exploit the glaze in its Cu^{2+}-stained turquoise form.

Perhaps the most striking and original of the various Chinese wares that used low-firing alkaline glazes are the *fa-hua* 琺華 wares that originated in northern China (see p. 512). *Fa-hua* ceramics are distinct from any Near Eastern ceramic style in that they used raised lines of trailed slip to separate the various alkaline-glaze colours (see p. 501). Inky-blue, aubergine and turquoise glazes dominate on *fa-hua*, which seems to be the last major innovation in northern ceramics. The style soon spread to southern China, where alkaline glazes were applied direct to high-fired porcelain bisque, and the white slips used to disguise the light-brown and buff-coloured northern stoneware clays were dispensed with. Green or yellow lead glazes were often used inside both northern and southern *fa-hua* wares and these glazes can also feature as outside details, where they play secondary roles to the colder alkaline colours. The popularity for *fa-hua* wares in China peaked in the late $+15^{th}$ to early $+16^{th}$ centuries when vessels of notable scale and complexity were made.

Fully quantitative analyses of early Chinese alkaline glazes (including the turquoise-blues) have emerged from two studies, an analytical campaign in Oxford in +1989, and work at the Musée de Louvre in +1997.[54] The first paper examined northern and southern Chinese alkaline glazes on eight vessels and one figure, made from the $+14^{th}$ to the $+18^{th}$ centuries, together with two examples of enamel-glass from a $+16^{th}$-century cloisonné incense burner. Six examples of *fa-hua* ware were among the ten objects studied. The +1997 paper examined a Hsüan-Te period turquoise-blue monochrome (discussed above) and also a $+14^{th}/+15^{th}$-century censer of northern style. Because these data derive from many kiln sites (mostly unknown) in both north and south China, and span some 500 years of varied production, numerous subtle differences appear in the analyses. These would consume many pages of commentary for full discussion so, for the sake of space, the entire data-set is presented here as a single table followed by some notes on the features that seem common to these various and separate traditions (Table 130).

Vessel 1: $+15^{th}$-century Tzhu-chou style jar with underglaze painting beneath blue black, turquoise-blue and amber glazes.
Vessel 2: $+16^{th}$-century northern *fa-hua* bottle vase.
Vessel 3: $+15^{th}/+16^{th}$-century northern *fa-hua* bowl.
Vessel 4: $+15^{th}/16^{th}$-century northern *fa-hua* ware jar.
Vessel 5: Cloisonné enamels on a $+15^{th}/+16^{th}$-century incense burner.
Vessel 6: $+16^{th}$-century porcelain *mei-phing* 梅瓶 vase, perhaps Ching-te-chen.
Vessel 7: Late Chhing dynasty Ching-te-chen *fa-hua mei-phing* vase.
Object 8: $+15^{th}/16^{th}$-century northern glazed figure.
Vessel 9: $+15^{th}$-century Hsüan-Te period Ching-te-chen turquoise-glaze dish.
Vessel 10: $+14/+15^{th}$-century North Chinese tripod censer with alkaline glazes.

[54] Wood *et al.* (1989), pp. 172–82; Vandiver *et al.* (1997), pp. 25–34.

Table 130 *Potassia-based Chinese alkaline glazes from north and south China: late Yuan to Chhing dynasties*[a]

Code	Colour	PbO	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	CuO	CoO	MnO	SnO_2	Total
1a	Blue-black	11.2	64.1	1.6	0.7	0.1	0.6	1.2	13.1	1.9	0.4	0.15	4.4	0.0	99.5
1b	Blue-black	14.8	61.7	1.8	0.7	0.1	1.2	1.2	10.7	1.8	0.5	0.2	4.9	0.2	99.8
1c	Dark-green	11.6	66.3	0.5	0.5	0.0	1.2	1.0	9.4	3.3	4.9	0.0	0.1	0.3	99.1
2a	Turquoise	16.2	63.5	0.6	0.3	0.0	0.6	1.3	7.2	5.7	4.5	0.0	0.0	0.2	100.1
2b	Aubergine	17.1	58.9	1.6	0.9	0.0	0.5	0.4	8.4	6.9	0.7	0.1	3.4	0.0	98.9
3a	Dark green	43.4	43.9	0.2	0.5	0.0	1.3	0.6	3.7	1.5	5.1	0.0	0.1	0.4	100.7
3b	Turquoise-blue	17.5	60.4	0.9	0.5	0.0	0.9	0.8	13.0	3.4	1.5	0.0	2.0	0.1	101.0
3c	Turquoise-green	13.6	62.9	5.8	0.6	0.1	0.5	0.5	11.8	0.8	3.4	0.0	0.0	0.1	100.1
4a	Trans. Turquoise	32.5	51.1	0.9	0.2	0.0	5.0	0.3	7.4	1.0	2.2	0.0	0.0	0.0	100.6
4b	Transparent	30.0	54.1	0.7	0.2	0.0	6.1	0.0	8.4	0.9	0.0	0.0	0.1	0.0	100.5
4c	Pale mauve	30.1	54.1	0.7	0.1	0.0	6.5	0.0	8.5	0.9	0.0	0.0	0.0	0.0	100.9
4d	Translucent	36.2	48.2	1.6	2.5	0.0	3.1	0.0	6.2	1.5	0.0	0.0	0.0	1.8	101.1
5a	Transparent enamel	29.5	47.5	0.3	0.3	0.1	6.0	-.-	12.7	0.6	-.-	-.-	-.-	-.-	97.0
5b	Turquoise enamel	29.0	49.0	0.3	0.2	-.-	6.0	-.-	12.6	1.0	2.6	-.-	-.-	0.1	100.8
6a	Purple-blue	0.7	73.2	3.1	0.7	-.-	0.7	-.-	12.3	1.5	2.4	0.6	5.7	0.4	101.3
6b	Turquoise-blue	1.1	76.3	1.0	0.4	-.-	0.9	0.2	13.2	2.7	4.0	-.-	-.-	0.5	100.3
7a	Purple-blue	15.3	59.7	1.4	0.4	-.-	0.3	0.3	11.1	3.3	4.8	0.5	3.4	0.5	101.0
8a	Purple-blue	1.0	65.2	3.2	1.1	-.-	0.3	-.-	18.8	3.6	3.8	0.4	3.3	0.3	101.0
8b	Trans. Turquoise	0.7	68.9	4.9	0.5	-.-	3.1	0.1	11.8	4.0	4.6	-.-	0.1	0.4	99.1
9	Turquoise	0.3	76.9	2.8	1.2	0.0	0.3	0.25	11.0	1.6	5.7	-.-	0.02	1.3	101.4
10a	Clear glaze	15.3	76.6	1.1	0.02	0.0	1.4	1.1	2.8	1.0	0.3	-.-	-.-	-.-	99.6
10b	Purple	12.4	58.7	2.35	1.2	0.2	0.95	0.9	13.9	2.1	0.2	0.17	6.3	-.-	99.4
10d	Turquoise	16.5	60.4	1.9	0.3	0.0	1.6	1.5	11.7	1.9	3.9	-.-	0.0	0.2	99.9

[a] Objects 1–8 Wood *et al.* (1989), p. 174, table 1; objects 9–10 Vandiver *et al.* (1997), p. 28, table II.

A number of obvious trends emerge from these figures, and these concern both the alkaline base-glazes, and the various glaze colourants used with them:

GLAZE-TYPES

- In all these analyses potassium oxide is the main alkaline glaze-flux (7.2 to 18.8% K_2O). Sodium oxide (when present) usually occurs at low levels (0.6 to 4%); exceptions do occur, such as 2a and 2b, which have appreciable soda contents, although potassia still dominates.
- Late Yuan and early Ming dynasty alkaline glazes from north China can contain substantial amounts of lead oxide, sometimes as a primary, sometimes as a secondary flux. Nonetheless the presence of considerable amounts of potassium oxide in the glazes ensures that their response to colouring ions is characteristically 'alkaline'.
- Most southern alkaline glazes (applied to porcelain) are low in lead and consist mainly of potassium oxide/silica mixtures. However, one single late Chhing dynasty example from Ching-te-chen showed use of some rather sophisticated lead-alkali enamels, while one set of northern analyses, from the alkaline-glazed figurine (8), was also very low in lead.
- One set of northern alkaline glazes (from vessel 4 a $+15^{th}$- to $+16^{th}$-century northern *fa-hua* jar) contained calcia as an additional stabiliser. These glazes are comparable to some contemporary Chinese cloisonné enamels on metal (vessel 5). In general, however, Chinese cloisonné enamels and Chinese *fa-hua* glazes have rather different compositional bases from the cloisonné enamels.
- The background glaze, on vessel 10 a $+14^{th}$-century censer embellished with lead-alkali coloured painted glazes, contained little alkali itself. It was essentially a high-firing lead glaze with an unusually high content of silica. No other example of this unusual glaze-type has been found in Chinese ceramics to date.

GLAZE COLOURANTS

- Aubergine and inky-blue-black effects are common in Chinese alkaline glazes, with both colours deriving from manganese-cobalt mixtures. In fact, wherever cobalt occurs in these compositions the element is always associated with large amounts of manganese. Many of these samples date to the late $+14^{th}$ and early $+15^{th}$ centuries, when iron-cobalt ores were the main pigments used on finer Chinese porcelains. Nonetheless, some Ching-te-chen folk porcelains of this time were decorated with manganese-cobalt ores that were probably Chinese in origin; the cobalt-rich pigments used with early Ming dynasty alkaline glazes seem to be of this same high-manganese type (see pp. 680–4).
- Where copper is used as a glaze colourant it is always associated with tin, most probably introduced to the glazes in the form of oxidised bronze.

- By combining copper and cobalt-manganese pigments, various purple glazes with blackberry or blackcurrant tones were possible. Similar glazes also appear on later Ching-te-chen monochromes.
- One *fa-hua* sample (the jar with the cloisonné glass-type compositions) showed the presence of tin in its yellow glaze. Lead-stannate yellow occurs in some early cloisonné enamels (+15th century), so this may be a further, but rather exceptional, parallel with cloisonné enamel technology.

Use of Saltpetre in Chinese Alkaline Glazes

Saltpetre is central to any discussion of Chinese alkaline glazes, and many first-hand accounts of its use in Chinese ceramics occur in the literature. Western observations include those of Père d'Entrecolles in +1712,[55] Vogt (via Scherzer's notes) in +1900[56] and Efremov in +1956.[57] Chinese references to the use of saltpetre in glazes include *Thao Shuo* (Description of Ceramics, +1774), which mentions that:[58]

the turquoise colour was composed of verdigris derived from old bronze with water and saltpetre added and mixed together.

Chiangsi Sheng Ta Chih (Great Gazetteer of Chiangsi, Province +1597) describes the 'kingfisher-green' glaze as being made from old copper (*ku-thung* 古銅), water and potassium nitrate (*hsiao-shih* 硝石, KNO_3).[59] Both Chinese accounts, however, omit the essential glass-forming oxide, silica.

Saltpetre therefore seems a prime candidate as the supplier of potassium oxide in Chinese alkaline glazes from the +16th-century onwards. Nonetheless, when we consider earlier examples of high-potassia silicates found in China, such as the problematic glass objects from Han dynasty tombs, another source of potassium oxide should perhaps be considered. That is the recrystallised liquor from the washing of wood ash, i.e. 'potash' or crude potassium carbonate.[60] Direct use of wood ash itself (washed or unwashed) is most unlikely, because of the low MgO levels that occur in these glasses and glazes. As Robert Brill explains, when discussing some later Chinese high-potassia glasses of the +7th to +14th centuries:[61]

[55] Tichane (1983), pp. 81, 86, quoting Père d'Entrecolles letter of +1712.
[56] Vogt (1900), p. 598.
[57] Efremov (1956), p. 493.
[58] *Thao Shuo*, ch. 3, p. 7a.
[59] *Chiangsi Sheng Ta Chih*, ch. 7, p. 26a. Modern interpretation is given by Li Chhüan-Chhing & Liu Chien-Yeh (1987), p. 20. Other recipes from this source include: antique yellow:black lead powder ground with red stone (Fe_2O_3) and purple: black lead, cobalt (*shih-tzu-chhing* 石子青) and sand powder (silica SiO_2). For list of recipes for colours see *Ching-te-chen Thao Lu*, ch. 3, pp. 9a–10a. For list of ingredients (for example, white lead), see *ibid.* pp. 10a–b; Sawyer (1951), pp. 25–6.
[60] There is also the problem that the term may itself be ambiguous: 'in all medieval cultures there was a confusion between the nitrates and the carbonates.' Needham *et al.* (1962), p. 110, note e. However, Needham *et al.* (1986), p. 96, also say: 'In China potassium nitrate was never confounded with sodium carbonate, as in the West, but rather with sodium sulphate and magnesium sulphate.'
[61] Brill (1991), pp. 38, 40.

all the dozens of analyses we have done of plant ashes themselves have correspondingly high MgO contents of the order of 3–5%, or even greater . . . Recrystallisation removes the magnesium, calcium and alumina from the ashes. It seems more likely that the Chinese glasses were made with saltpetre, which, recrystallized or not, might have been low in MgO.

As Table 65, p. 461, shows, the washing of a potassia-containing wood ash can place most of the potassium oxide in solution, while leaving other oxides largely undissolved. Crystallisation from this liquor should produce usefully pure potassium carbonate.[62] Analyses of Han dynasty stoneware glazes (see p. 467) suggest that potassium oxide had been removed during ash-washing. Whether potash was ever recovered from the process at this time is still unknown.

Potassium carbonate is highly soluble (not to say deliquescent) and needs to be fritted with silica before it can be used in glazes. Even so, its use in early Chinese glass and glaze cannot be wholly discounted, although saltpetre (potassium nitrate) is perhaps the more likely candidate, particularly as the material can be used in an unfritted state.

Nature and Occurrence of Saltpetre

Saltpetre dissolves to some extent in water, but its solubility decreases markedly as the water gets colder. For example, 100 centilitres of water at 18° will dissolve 30 grams of potassium nitrate, but at 5°C only 17 grams.[63] Solution of saltpetre also lowers the temperature of the water itself through an endothermic effect that further limits solution of the salt.[64] The material occurs in nature when nitrogenous organic matter, whether animal or vegetable, is exposed to atmospheric influences, in the presence of strong bases, or it may be 'farmed' in special 'nitre beds' by burying organic remains in lime-rich soil and watering regularly. In both cases the saltpetre occurs as a white efflorescence. The commonest Chinese name for potassium nitrate is *hsiao-shih* (硝石, 'solve stone') which refers to its fluxing properties, while another Chinese name, *ti-shuang* 地霜 ('ground frost'), describes its natural form, which is abundant in Honan, and also in Szechuan and Shansi provinces.[65]

The use and occurrence of saltpetre in China has been studied in some detail (particularly in these volumes), most notably for its properties of 'flux and solubilisation' and for its use in gunpowder. Needham *et al.* note that an early mention of *hsiao-shih* (although without details of its nature and use) occurs in the -4^{th} century, while more specific references to the purification of saltpetre refer to the $+1^{st}$ and $+2^{nd}$ centuries. Of a somewhat later period Needham notes that 'all the alchemical books of the Thang period mention solve-stone (saltpetre) as a matter of course'.[66]

[62] The first patent ever issued in the United States concerned the making of potash from wood ash. It took 360–450 tonnes of wood to make 1 tonne of potash, that is a yield of about 0.4%.
[63] Anon. (1877), p. 692.
[64] See a full discussion of this effect in Needham *et al.* (1976), p. 225, note d.
[65] See Needham *et al.* (1986), p. 96, note c.
[66] *Ibid.*, pp. 96–8.

Its key role in ceramics, as a dissolver of silica, was mentioned, theoretically, by the alchemist Sheng Hsüan-Tzu 昇玄子, whose earlier work was quoted in a reference of +1150: 'if you heat a piece of white quartz, then put a drop of saltpetre on it, it will sink in.'[67] This seems more a description of a phenomenon than an account of the basis for an applied technology.

To sum up on saltpetre, we can note that the common name for the material (*hsiao-shih*) was in use in China in the -4^{th} century, and that saltpetre refining was mentioned in a Chinese text that referred to the $+1^{st}$ and $+2^{nd}$ centuries. By the Thang dynasty, references to saltpetre were legion. Its earlier use in China was mainly as a flux, and as a material that rendered the insoluble soluble. It therefore seems possible that saltpetre could have served as the primary flux in Chinese alkaline glasses and glazes from the very beginning of their production, although this is presently unproven.

[67] Needham *et al.* (1980), p. 188.

THE DEVELOPMENT OF ENAMELLING IN 'FOREIGN COLOURS' IN THE +18TH CENTURY

LATER CHING-TE-CHEN OVERGLAZE ENAMELS

We know from Père d'Entrecolles' writings of +1722 that saltpetre was an important ingredient in Khang-Hsi monochromes at Ching-te-chen which, like most Ching-te-chen overglaze effects, were transparent glazes, coloured by metallic ions in solution. At about the time that d'Entrecolles left Chiangsi province for Peking in +1723, translucent and opaque overglaze colours were being introduced to Ching-te-chen, after some initial experiments with the colours in Peking. These eventually transformed the appearance of Ching-te-chen overglaze enamelling from its 'water-colour' style to an opaque, and sometimes near-impasto, enamelling method that was closer in appearance to oil-painting. Europeans identify this process as the change from the '*famille verte*' to the '*famille rose*' styles, that is from an enamel palette dominated by green to one in which ruby-red and pink operated as major colours.[68]

In essence, this development involved the introduction of three new overglaze enamel colours: translucent ruby enamel, opaque white and opaque yellow. The overglaze enamel blue of the Khang-Hsi reign period was also used more extensively. The ruby enamel was coloured with colloidal gold, and was therefore a technological cousin to the more ancient copper-red. The opaque white derived from fine crystals of lead arsenate ($PbAs_2O_4$) that formed in the enamel glazes, while the opaque yellow exploited lead stannate ($PbSnO_3$) often known in the West as the 'lead-tin yellow'. When the translucent ruby enamel was applied thinly over the opaque arsenic-white enamel, or mixed with it, a bright overglaze-pink was possible, hence the '*famille rose*' description.

Chinese scholars have used many terms for the new colours. A +1734 entry in Thang Ying's *Thao Chheng Chi Shih* (see p. 27) mentions decoration using *yang-tshai* 洋彩 ('foreign colours') and *fa-lang tshai* 琺瑯彩 ('enamels'). The term *yang-tshai* gradually gained precedence over *fa-lang*, which fell into disuse, and *yang-tshai* was used all through the Chhien-Lung reign period. Another name for '*famille rose*' was *fen-tshai* 粉彩 ('powdered colours'), but this was not current till the +19th century, and may not have appeared till the very end of the Chhing dynasty or the Republican period. *Fen-tshai* is a common term in *Thao Ya* (+1910) and in *Yin Liu Chai Shuo Tzhu* (*c.* +1912–25), the latter book also describing decoration in *ying-tshai* 硬彩 ('hard colours', i.e. *famille verte*), *juan-tshai* 軟彩 ('soft colours', another name for *famille rose*) and *fen-tshai*.[69]

[68] Terms first adopted by Jacquemart (1873).
[69] Ts'ai Ho-Pi (1992), pp. 6–8, 17–19.

Although the three *famille rose* colours (plus overglaze-blue) transformed the appearance of Chinese porcelain, from the early +1720s onwards their use in silicate pyrotechnology was by no means new. The gold-ruby effect, for example, had been used in Roman glass, and it has been studied in detail in the case of the +4th-century Roman cage-glass masterpiece, the Lycurgus cup, which has the remarkable property of dichroism. That phenomenon means that the cup appears pea-green in reflected light and a deep ruby-red in transmitted light. The colour of this glass derives from the presence of colloidal gold and silver in concentrations of 0.004% and 0.03% respectively, while the glass itself was a soda-lime composition of standard Mediterranean type.[70] The colour was promoted by in-glaze reducing agents (iron and antimony) and also by heat-treating (that is 'striking') the glass after manufacture.[71] Brill notes that his results show that:[72]

> There is a more or less continuous history of the use of gold and silver as glass colorants, which reaches back over twelve centuries to their use by the glass-makers of the Islamic period. Now . . . that history has been extended back to late Roman times.

The Islamic use of gold-ruby glass is also noted by Hans Wulff:[73]

> Al-Bīrūnī [*d.* +1038] describes the use of gold for the preparation of the famous ruby glass and ruby glazes and says that one part of gold in 50,000 of frit gives a deep ruby colour, in 100,000 parts a bright red.

The amounts of gold mentioned by Wulff (0.005 and 0.0001% Au) seem close to Roman glass-making practice, but far lower than the gold levels found in Ching-te-chen overglaze enamels from the late +1720s onwards (0.1–0.3% Au). The latter results were established at the Massachusetts Institute of Technology in +1985.[74] The minute amounts of gold used in the Roman and Persian examples are more typical of glasses than glazes. This is probably because colourant levels tend to be much lower in glasses (which are relatively thick) than in thin glazes applied to light grounds, such as overglaze enamels applied to very white porcelain glazes. Kingery and Vandiver studied three Chinese gold-ruby enamels of the period +1730–50, with the following results (Table 131).

It is noticeable that tin is absent from one of these three Chinese gold-pink enamels. This is significant because much tends to be made of the European discovery of the 'purple of Cassius' technique, in relation to the Chinese *famille rose* palette.[75] For example, Harry Garner, writing in the Transactions of the Oriental Ceramic Society in +1969, said:[76]

[70] Barber & Freestone (1990), pp. 33–45.
[71] Brill (1965), pp. 223.4, 223.11.
[72] *Ibid.*, p. 223.11.
[73] Wulff (1966), p. 147.
[74] Kingery & Vandiver (1985), pp. 363–81.
[75] Named after Andreas Cassius the elder (*d.* +1673). See Needham & Lu (1974), pp. 268–70, for an account of the process's discovery and early use in Europe.
[76] Garner (1970), p. 1.

Table 131 *Chinese ruby-red overglaze enamels containing gold*[a]

Object	PbO	SiO_2	Al_2O_3	FeO	CaO	MgO	K_2O	Na_2O	CuO	CoO	MnO_2	SnO_2	Au	Total
vase	47.3	45.1	0.6	0.1	0.3	0.1	2.1	2.75	0.03	0.0	0.02	0.19–0.26	0–0.12	98.4
bowl	47.4	41.85	0.6	0.1	0.1	0.05	8.4	0.6	0.04	0.0	0.0	0.00	0.00–0.31	99.14
plate												0.0–0.29	0.0–0.29	

[a] Kingery & Vandiver (1985), p. 374.

the term *yang cai* [*yang-tshai*] indicates that the technique was derived from the west and we have long been familiar with the fact that somehow the technique and probably some of the materials for manufacture were imported from Europe.

Garner, who was a mathematician and aeronautical engineer as well as a knowledgeable collector of Chinese art, based his study on examination of European enamels applied to copper, particularly those of +17th-century France and South Germany. Such artefacts used pink enamels based on colloidal gold produced by the so-called 'purple of Cassius' technique. This was a method for forming colloidal gold by dissolving gold in aqua regia, to produce gold chloride, followed by reduction of the gold chloride to metallic gold, usually by the addition of tin compounds.[77] Tin was not always used in this process, as the colloidal gold can also be precipitated by magnesia or by alumina.[78]

Because of the usefulness of this technique in the preparation of colloidal gold that would dissolve and disperse easily into molten glass, it is often assumed that makers of Chinese gold-ruby enamels would have needed this technology in order to produce successful overglaze ruby-coloured enamels based on gold. The ancient use of gold-ruby glass in Roman and Near Eastern glass technology shows this to be a flawed argument,[79] but it was assumed from this reasoning that any Chinese knowledge of gold-ruby enamels and glasses must have come from Europe. Kingery and Vandiver, however, doubt the use of the purple of Cassius technique in +18th-century Chinese ruby-red enamels for the following reasons:[80]

[77] Anon. (1877), p. 110, gives one method for making purple of Cassius: '20 grams of gold are dissolved in 100 of aqua regia, made by the addition of 20 parts of nitric acid to 80 of commercial hydrochloric acid, the solution being evaporated to dryness in a water bath. The residue, after being dissolved in water, is filtered and diluted with 7 or 8 decilitres of water, and placed in contact with tin filings; a vigorous action ensues, and in a few minutes the water becomes brown, and deposits a purple precipitate, which should be washed and dried at a gentle heat. This purple possesses the following composition – Stannic acid 32.7; Protoxide of tin 14.6; Protoxide of gold 44.8, Water 7.8.' This gives a material with about equal weights of tin and gold, but the assumption that the gold is in an oxide state seems dubious.

[78] Hainbach (1907), pp. 170–3, gives nine traditional procedures for making colloidal gold from gold trichloride: seven use tin in some form while two do not.

[79] Barber & Freestone (1990), p. 44, note: 'Direct dissolution of metallic gold into molten glass can occur but, because of segregation of the metal repeated stages of crushing, grinding and remelting would be required to produce a homogeneous ruby glass. Such a process, while possible, is considered to have been uneconomic for practical purposes in the post-medieval period. However, such considerations are unlikely to have constrained the production of luxury glass in the Roman period.'

[80] Kingery & Vandiver (1985), p. 378.

We have analysed a Vincennes-Sèvres rose coloured enamel and a Mennecy rose-coloured enamel made in France . . . The analyses give a higher tin content than is found in the Chinese gold colors. In addition, the colloidal gold particles are found to be in association with a mass of crystalline material in a structure quite different from that of the Chinese pigment in which the gold particles are suspended in glass, with none of the surrounding material resulting from the 'purple of Cassius' precipitation . . . We conclude that the *famille rose* palette used colloidal gold as a colorant, but that it was not formed by the European process of Purple of Cassius precipitation. The evidence indicates that the rose pigment was prepared by making up a ruby-red glass, well known to glass-makers and enamellers of the time.

As Kingery and Vandiver inferred, the absence of tin in the Chinese gold-ruby enamels did not necessarily rule out a European influence on the Chinese technology, as European precedents for making gold-red glass *without* tin also existed. Examples of tin-free European gold-ruby glasses appeared in Benevento Cellini's treatise of *c.* 1560 and Antonio Neri's *De Arte Vitraria* of +1611.[81] One could also add that West Asian techniques for making gold-ruby glass may well have survived, and the possibility of non-European sources for this Chinese technology can not be ignored.

Although Kingery and Vandiver point out that the tin contents of the gold-rose Chinese enamels that they had examined proved much lower that their European equivalents, two of the Chinese enamels they studied did show levels of tin and gold in about equal proportions. In these two +18th-century Chinese ruby-pinks the tin-to-gold ratio is characteristic of at least one method for making purple of Cassius (see note 78).

The subject has been explored further by Mills and Kerr who studied Chinese and European rose-pink enamels by the non-destructive technique, airpath EDXRF.[82] Because the previous sample base for *famille rose* enamels had been so small, both with regard to Chinese enamelled pieces and, to an even greater extent, comparable European examples, a larger range of some 48 objects was examined. They comprised 21 Chinese porcelains dating between +1730 and +1750,[83] eight +19th-century Chinese porcelains, two glass bowls, four 'Canton' enamels on metal and thirteen European ceramics.

Essentially these results were fascinating but inconclusive: one +18th-century Chinese gold-pink enamel contained tin, while others did not. One early Meissen

[81] Neri (+1611, with English version +1662). Kingery & Vandiver, pp. 378, 381, notes 27, 28. The +17th-century English translation of Neri's method runs: 'A Transparent Red. Calcine Gold with aqua regis many times, pouring the water upon it five or six times then put this powder of Gold in earthen pans to calcine in the furnace till it becomes red powder which will be in many days, then this powder added in sufficient quantity and by little and little, to fine Crystal glass which hath been often cast into water will make a transparent red of a Rubie as by experience is found.' The English editorial comment speculates (bizarrely) that the conversion of gold to ruby may be a kind of decomposition process: 'Rubies are frequent where Gold is found, and therefore 'tis consentaneous that gold doth degenerate into this jewel.' *Ibid.*, p. 351.

[82] Mills & Kerr (1999).

[83] It was thought that the Chinese objects would have been decorated using an enamel technology that, although less than twenty years old, was already well established.

gold-pink enamel contained tin and another not. Of two Chelsea gold-pink enamels one used both gold and tin together, the other gold alone. A French Mennecy cup (*c.* +1750–60) contained both gold and tin in its pink enamel, as Kingery and Vandiver had found with their own Mennecy sample.[84] However, some broad conclusions could be drawn. Of the +18th-century vessels analysed, the most closely related compositions to Chinese porcelain colours were those of Canton enamels, confirming a link between the technologies of enamelling on ceramic and enamelling on metal. Further, it seems that although Chinese +18th-century enamels used ruby glass as a base, they were compositionally dissimilar to contemporary glass vessels. Finally, all the +19th-century ruby-pinks contained tin, suggesting a possible change in technology in the later Chhing dynasty.[85]

THE CHINESE GOLD-RUBY ENAMEL

What can then be said on this subject? At its simplest we can say that the *famille rose* pink enamel based on gold was a new colour in Chinese ceramics, glass and metal enamelling. The technology had a long history beyond China, first in Roman and Near Eastern glass, then in Renaissance metal enamelling, and then in European ceramic enamels in the late +17th century. Production of this fine gold-ruby colour was facilitated in Europe by the discovery of the purple of Cassius technique (*c.* +1640), an approach that was adopted for making European ceramic enamels in the +17th century. It must be noted that successful gold-ruby glasses could and can be made without this acid-solution technique for gold, and even the 'purple of Cassius' method itself does not always use tin compounds.

At some point in the early +18th century a gold-ruby glass technology was adopted in China and used to make ceramic and metal enamels. Some of these Chinese ruby enamels contained both gold and tin while others contained gold alone. How this technology was introduced to China is still unknown, although there is some useful literary evidence, from both China and from Europe, on some circumstances surrounding its adoption.

In advance of further research, three possibilities can be advanced. The first possibility is that both metal and porcelain enamels derived influence from achievements in the glass factories, which themselves benefited from European trade in coloured glass cullet, from Europe to China, in the early Chhing dynasty.[86] Some Chinese textual sources seem to support this hypothesis, though the small number of artefacts analysed do not. European influence on the improvement of Chinese glass-making technology can be demonstrated by the Khang-Hsi emperor's

[84] Mills & Kerr (1999), p. 261, table 3. See also Kerr (2000).

[85] Kingery & Vandiver (1985), p. 378, recorded tin in two +18th-century Chinese pinks, whose content was lower than that found in European pinks.

[86] Curtis (1997), pp. 97–8. Curtis (2001) describes the establishment of the glass factory on a piece of land next to the French Jesuits' church within the walls of the Forbidden City, and placed under their care. The glass factory used the knowledge of craftsmen from Po-shan 博山 in Shantung province, see Chu Chia-Chin (1982), p. 67, and Chang Wei-Yung (2000).

commission in +1695, for the Bavarian Jesuit Kilian Stumpf to establish a glass-works in Peking. This was followed by a number of orders to Europe from China for coloured glass cullet for enamel decoration, with Emily Byrne Curtis suggesting that much of this material derived from Venetian glass factories.[87] Venice was already making gold-ruby glass in the +17th century, as recorded by the recipe books of the Venetian glass-maker Giovanni Darduin (+1585–1654), which include three for gold-ruby glass.[88] As noted above, the Florentine glass-maker Antonio Neri's (+1576–1614) book *De Arte Vitraria* also contained a recipe for gold-ruby glass, in this case made without the use of tin.[89]

The second suggestion is that certain enamel colours, especially pink, were introduced directly from Europe. European literary sources support this research direction, whereas analyses suggest that Western influence might possibly not have been felt until the +19th century. A third scenario states that enamels developed for use on cloisonné were connected with the development of certain colours on ceramics.[90] The compositional resemblance of Canton enamels to *famille rose* adds strength to the theory that the technologies of enamels on metal and on porcelain were interconnected. Furthermore, there was connection between the development of glass-making and enamelling on metal, glass and porcelain at the Palace factories in Peking, whose history is outlined here.

Historical Background to the Development of the New Enamels on Porcelain, Glass and Metal

Khang-Hsi was eager to copy foreign enamels and to manufacture them in his own workshops. In order to curry favour, during the ninth month of +1716 the Provincial Governor of Kuangtung sent two enamel craftsmen called Phan Chhun 潘淳 and Yang Shih-Chang 楊士章 to the capital with supplies of peach-red enamel derived from gold, that had been formulated by Phan.[91] It is possible that Phan's success had been facilitated by contact with foreigners, from whom he had learned the secret of obtaining pink from colloidal gold. According to French scholars the so-called 'purple of Cassius' material was brought to Canton as early as +1683. While this early date cannot be assured, it is quite possible that the technique was introduced at an earlier date to the south of China than to the north.[92]

[87] Curtis (1994), pp. 97–8; Curtis (1997), p. 98.
[88] Horn (1998), p. 156.
[89] Neri (1611). The English version of his book, published in London in +1662, describes the subject in Book VI, on pp. 145–57: 'The Sixth Book. Wherein is Shown the way to make all the Gold-Smiths Enamels, to Enamel upon Gold in divers Colours, with rules, and the materials which colour, and what fires make those Enamels, with exact diligence and clearest demonstration possible.'
[90] Connections between metal enamels and glazes were explored in Wood, Henderson & Tregear (1989), and Henderson, Wood & Tregear (1990).
[91] Lü Chien (1981), pp. 93–4.
[92] Jenyns & Watson (1963), pp. 220, 223; Garner (1970), pp. 2–4; Needham & Lu (1974), pp. 268–71.

The impetus for developing a new enamel palette was spearheaded by the Khang-Hsi and Yung-Cheng emperors, spurred on by receipt of foreign enamelled treasures as gifts from Western embassies. The interest in enamelling was part of a larger initiative on the part of Khang-Hsi. After his reorganisation of the imperial kilns in +1681, he desired to attract expertise in craftwork, especially from abroad. Government officials all over the empire were ordered to keep a close watch on Western missionaries in their jurisdiction, so that they could both curtail conversions and also send any individuals with unusual artistic skills to court.[93] This is how the enamel workshop at court started in the early +18th century, its existence mentioned in a letter of Matteo Ripa of +1716:[94]

His Majesty having become fascinated by our European enamel and by the new method of enamel painting, tried by every possible means to introduce the latter into his imperial workshops which he had set up for this purpose within the Palace, with the result that with the colours used there to paint porcelain and with several large pieces of enamel which he had had brought from Europe, it became possible to do something. In order also to have European painters, he ordered Castiglione and I to paint in enamels: yet each of us, considering the intolerable slavery that we would have to suffer by having to stay away from morning to evening in a workshop filled with such a crowd of corrupt people within the Palace, we excused ourselves by saying that we had never learnt that art. In spite of this, forced by imperial command, we obeyed, and went on the 31st of the month. As neither of us had learned this art, and making up our minds that we would never want to know it, we painted so badly that the Emperor, on seeing what we had done, said 'enough!' Thus we found ourselves free from the conditions of a galley-slave.

Western-style enamel paints used to decorate metal and ceramic vessels in the favoured Western style were imported from Europe. They were so treasured that special vessels were selected for decoration. For example, during the Khang-Hsi and early Yung-Cheng reign periods, decoration was often added to Ming ceramics, while in the Chhien-Lung reign period it was added to Yung-Cheng pieces.[95] In the Khang-Hsi reign enamels were also painted on to the surface of I-hsing red stoneware teapots, and these vessels bore the mark *Khang-Hsi Yü Chih* 康熙御制 'made by imperial command of the Khang-Hsi emperor' indicating a direct, supervising interest on the part of the ruler.[96] This personal commitment to craft excellence was demonstrated by another event of +1716. The Governor of Kuangsi province, Chhen Yüan-Lung 陳垣龍, was presented by the emperor with a polychrome painted red glass snuff bottle, ink box, water container and incense box. In his memorandum of appreciation of the imperial gift, Chhen wrote that:[97]

[93] Ts'ai Ho-Pi (1992), pp. 1, 11.
[94] M. Ripa, *MS. Diary*, 1716, *AAH-A* 262. Quoted in Loehr (1964), p. 55.
[95] Kerr (1994), pp. 486, 489.
[96] Exquisite I-hsing wares with enamel decoration and *Yü Chih* 御制 marks in the National Palace Museum, Taipei, are illustrated in K. S. Lo (1986), pls. XL–XLIV, pp. 133–135.
[97] *Kung Chung Tang Khang-Hsi Chhao Tsou Che, Tshe* 6, pp. 602–6.

According to palace personnel, the four items were fashioned and fired after extensive searching for the true method, and under the supervision of the emperor.

Jesuit missionaries, following Chinese custom, made gifts of European objects on their arrival at court and on the emperor's birthday. Among such gifts was enamel, mentioned in a letter from Jean de Fontaney to Paris, written on 25 August +1687 from Ning-po. Fontaney requested paintings on enamel and enamelled objects, to surrender as gifts.[98] It is probable that in +1715 Giuseppe Castiglione brought some enamelled vessels of the kind so highly prized by emperor Khang-Hsi.[99]

Enamelling research was carried out in imperial workshops under the direction of the Imperial Household Department, located in the Hall of Moral Cultivation (*Yang-hsin Tien*, see pp. 27 and 196). After +1718, larger premises were needed, demonstrating the growing importance of the craft.[100] Techniques gradually improved, though there were still problems. Extant vessels in the Palace Museum, Taipei (from the former imperial collection) show defects such as burst bubbles in the enamel, caused by firing at a higher temperature than appropriate.[101] Nevertheless, when the Governor of Kuangtung sent a French Jesuit with enamel painting skills to court in the sixth month of +1719, the priest discovered that Chinese craftsmen already had a certain competence in enamel firing.[102]

The palace liked to show off its achievements. In +1721 two embassies came from Europe, the first from Pope Clement XI on 2 January. His legate was shown many pieces of enamelled porcelain from the imperial table-service, whereupon the emperor graciously presented gifts of Chinese enamelled ware including a snuff bottle, a box and ten vases. The second embassy came from Peter the Great on 10 February, and was sent home with a set of enamelled gold cups and enamelled snuff bottles made in the imperial workshop.[103]

The Yung-Cheng emperor continued progress made in the research and manufacture of enamels, and top-quality wares were achieved during his reign period. The very first year of his reign (+1723) saw the largest number of workers and supervisors appointed to the workshop of any year of the Chhing dynasty, while personal comments by the emperor in +1728 and +1732 showed his keen interest in standards, content of decoration, and achievement of individual painters in the workshop.[104] Collective contributions were made at that time by a combination of skills from artisans in the palace ateliers, Western painters, and craftsmen sent from Kuangtung and Chiangsi provinces.

Enamelling was carried out in the palace in workshops including those in the Institute of Indulgences (*Ju-i Kuan* 如意館) where the painters worked, using small

[98] Loehr (1964), p. 52.
[99] Beurdeley (1971), p. 26.
[100] Ts'ai Ho-Pi (1992), pp. 1, 12.
[101] Chang Lin-Sheng (1983), pp. 25–38, notes 14–16.
[102] Jenyns (1963), pp. 225–6.
[103] Loehr (1964), pp. 56–7.
[104] Ts'ai Ho-Pi (1992), pp. 2, 12.

muffle kilns (see pp. 207–8). Some work was also pursued in workshops in the Summer Palace (*Yüan-ming Yüan* 圓明園).[105] A muffle kiln was built there in +1731 and workshops furnished. Among the items ordered were six large tables, one standing cabinet, six stools, two water tanks and a firescreen.[106] The Superintendent of all enamelling work was Prince I (怡親王, Hereditary Prince of the First Rank, Yin-Hsiang 胤祥) a favourite younger brother of the Yung-Cheng emperor. Also important were the designer Hai Wang 海望 from the Imperial Household Department and the painter Shen Yü 沈喻, a Vice Director in the Imperial Household Department. Thang Ying 唐英 had also started work.[107] Imperial standards were exacting, and memorials sent in +1724 and +1726 indicated that firing processes were still not fully under control, leading to some breakages. Comments were made that the enamels were too coarse and that they must be produced with more finesse in the future.[108]

In the fourth month of +1726 Western diplomats presented fourteen enamel colours to court.[109] Another visitor Stefano Signorini wrote from Peking on 6 November +1727 with some urgency, because a rumour had been spread that either he or a companion, both recent arrivals at court, were enamellers. Both the Yung-Cheng emperor and the 'Thirteenth Prince', i.e. Prince I, were very suspicious because both Europeans denied knowledge of enamelling:[110]

> on account of the great desire which they have for such an art, which although it is practised in Peking, yet the product is quite coarse, and the workers are not able to succeed in something that was ordered by the Emperor some time ago.

Court archives noted that Westerners said that '*doermendina* oil' was used in mixing powdered glass to fire enamel colours, so a search was made in the Hall of Military Glory[111] to find such a material.[112] In the seventh month of +1728 over 30 catties of the oil were found (nearly eighteen kilograms), including four-and-a-half bottles presented by the Portuguese envoy Alexandre Mettello de Sousa Menezes.[113] In the third month of +1729 the Acting Provincial Governor of Kuangtung province sent four glass bottles of camphor oil from Portugal, whereupon an edict was issued to use them for firing enamels.[114] These actions throw light upon one of the problems Chinese artisans encountered in trying to mix and fire Western-style enamels. Traditional Chinese lead-fluxed enamels were mixed with glue for application. The

[105] Chu Chia-Chin (1982), pp. 67–76; Hucker (1985), pp. 273, 596; Sung Po-Yin (1997), pp. 65–84.
[106] Chu Chia-Chin (1982), p. 68.
[107] *Ibid.*, pp. 67–76.
[108] *Nien Keng-Yao Tsou Che* ('The Imperial Reports of Nien Keng-Yao'), ch. 1, p. 133. Nien Keng-Yao 年羹堯 was a senior government official and younger brother of Nien Hsi-Yao 年希堯, Supervisor of the imperial porcelain factory, cf. Hummel (1970), pp. 587–90. Ts'ai Ho-Pi (1992), pp. 2, 13.
[109] *Kuangtung Thung Chih*, ch. 58, p. 20, cited in Chang Lin-Sheng (1983), note 28.
[110] Loehr (1964), pp. 58–9.
[111] *Wu-ying Tien* 武英殿, a palace building that housed the Imperial Printing Office, cf. Hucker (1985), p. 574.
[112] Chu Chia-Chin (1982), p. 67; Anon. (1987a), pp. 111, 125, pl. 19. *Doermendina* oil is a transliteration of an imported oil, probably toluene (methyl benzene, $C^6H^5.CH^3$).
[113] Anon. (1987a), pp. 111, 125.
[114] *Ibid.*, pp. 111, 125–6, pl. 20.

new enamels contained silicates of borax, and in the early +18th century the palace seemed to believe that oil made a better medium.

In the second month of +1728 an imperial order had instructed enamel craftsman Sung Chhi-Ko 宋七格 to make enamels. In that same month Shen Yu and Thang Ying (who was sent in August of +1728 to assist in imperial porcelain production at Ching-te-chen, see p. 196) submitted a memorial to Prince I that recorded the experimental firing of pieces decorated with Chinese enamel materials obtained from the palace glass factory, as opposed to imported ones. By the seventh month, Prince I had given Western enamel materials in nine colours to Sung Chhi-Ko, plus nine newly made colours, and ordered him to make 300 catties of each type at the palace glass factory. Successful firing was achieved.[115]

In the autumn of +1728 the palace sent the enamel paints created in the glass factory to Nien Hsi-Yao 年希堯, the current Superintendent of the imperial porcelain factory at Ching-te-chen, who in exchange sent a potter expert in applying soufflé glazes to the palace. In +1729 460 plain white porcelain vessels from Ching-te-chen, their firing quality personally supervised by Nien Hsi-Yao, were sent to Peking for enamel decoration, and in that same year four expert porcelain painters (who already had knowledge of working with enamels) were sent to the workshop in Peking.[116] Nien Hsi-Yao was interested in foreign techniques and decorations, and collaborated with the Jesuit Castiglione in translating and adapting a Western book on projection and perspective in art.[117] Thereafter both Nien and his successor Thang Ying sent a regular supply of fine blanks to court for enamelling.

However, on 23 September +1729 Jesuit priests in Peking were still requesting an expert artisan from Europe 'especially in properly baking the enamel, a thing which the Chinese do not know how to do.'[118] This discrepancy between European and Chinese appraisals of Chinese proficiency in enamelling was summed up by Garner's rather extreme view that 'even as late as +1730, [the Chinese were] unable to make enamels up to the European standards at the time.'[119] By contrast, Chinese records show that in +1730 the Yung-Cheng emperor was sufficiently pleased with a pair of enamelled snuff bottles decorated with birds and flowers, to reward both the painter Than Jung 譚榮 and the enamel firing craftsman Teng Pa-Ko 鄧八格 with twenty ounces of silver. Court artisans gradually developed expertise in making enamelled wares, a record count being the achievement of 428 perfect pieces.[120]

[115] Ts'ai Ho-Pi (1992), pp. 3–4, 14. Chu Chia-Chin (1982), p. 67.
[116] Ts'ai Ho-Pi (1992), pp. 4–5, 15.
[117] The Chinese text was entitled *Shih Hsüeh* 視學 and was an adaptation of Andrea Pozzo's treatise *Perspectiva Pictorum et Architectorum*, of which there were two editions with hand-written notes in the margin in the former Jesuit library in Peking. *Shih Hsüeh* came out in two editions in +1729 and +1735, the second containing additional diagrams to illustrate the principles of perspective. Cf. Hummel (1944), p. 590; Scott (1993b), pp. 250–1.
[118] Loehr (1964), p. 57.
[119] Garner (1970), p. 5.
[120] Chu Chia-Chin (1982), p. 68; Wang Chien-Hua (1993), p. 52.

Several exceptionally fine porcelain vessels still in the National Palace Museum can be matched with specific mention in the imperial archives for +1723, +1725, +1731 and +1732.[121]

Enamelling after the Yung-cheng Reign Period

Prince I died in +1730, and the loss of his energetic supervision caused a gradual decline at the palace enamelling workshops. During the Chhien-Lung reign period, production of enamels on porcelain shifted to the imperial factory at Ching-te-chen, though enamelling on metal continued at the palace until the tenth month of +1789.[122] In the Yung-Cheng reign period a number of court painters had been employed painting enamels, which guaranteed high quality, but in the Chhien-Lung reign period many of these artisans were promoted to other posts, and a shortage of skilled decorators occurred. Many enamel decorators were also newly appointed in the very first year of the reign, another contributing factor to the shift in activity to Ching-te-chen.[123]

In the early Chhien-Lung reign period *c.* +1736–50, however, a number of top-quality enamelled wares were made at the imperial kiln at Ching-te-chen under the auspices of Thang Ying. Thang Ying described *yang-tshai* 洋彩 as being a version of *wu-tshai* 五彩 ('five colours') done in imitation of Western styles (*fang hsi-yang* 仿西洋). The most skilled painters were employed with a long training period. Colours were first tested by painting and firing a thin plaque of plain porcelain. The colours used were the same as those employed in cloisonné enamelling, and they were mixed with three different media: fragrant plant oil (like turpentine), liquid gum and plain water. The oil-based colour was good for painting on initial designs, the glue-based colour was good for thin washes and the plain water-based colour built up painting in relief.[124]

Some of the major commissions were recorded. Thus in the fifth month of +1737 an order was received for various vases and Thang was told to allow craftsmen to paint different designs as they wished, while in the eleventh month bowls in *yang-tshai* colours were ordered and completed the next month. In the eighth month of +1742 various bowls and plates with *yang-tshai* colours, brocade patterns and landscapes were ordered. In the tenth month of +1742 Thang met a kinsman in Pho-Yang 鄱陽 on his way back to Chiu-chiang 九江 and received imperial poems for porcelain decoration, so on the 29th he returned to Ching-te-chen and assigned his

[121] Ts'ai Ho-Pi (1992), pp. 5–6, 16–17.

[122] Yang Po-Ta (1981), p. 20, who mentions limited numbers of official enamelled wares in the late +18th and early +19th centuries; Chang Lin-Sheng (1983), p. 35.

[123] Ts'ai Ho-Pi (1992), pp. 9–10, 20.

[124] Thang Ying's description of pottery-making no.17, in *Thao Shuo*, ch. 1, p. 10b. See also *Ching-te-chen Thao Lu*, ch. 1, p. 6a.



Fig. 149



Figs. 149–50 A pair of vases with Chhien-Lung reign marks and imperial poems

assistant Tshui Lao-Ko 催老格 and other expert craftsmen to make the requested ware. By the seventeenth day of the eleventh month, six pairs of inscribed vases were made and dispatched to court, and they received acknowledgement and approval. In the eighth month of +1743 Thang received imperial poems to inscribe on vases, and four pairs were finished in the ninth month.

In the second month of +1744 Thang submitted a report on his personal endeavour in making a batch of snuff bottles, despite the clay being frozen, and his being without workers or heated kilns. Snuff bottles were usually fired in the winter when all the other kilns were inactive, because they could be baked in small muffle kilns using grass and brushwood. In the third month of +1744 Thang sent 40 snuff bottles along with 26 dishes and bowls via a court official and was told that only 40 snuff bottles were needed every year and not to make more. In the fifth month he again sent ten bowls and 40 snuff bottles in various 'foreign colours'. In the first month of +1745 Thang supervised production of *mei-phing* 梅瓶 vases with lids in *fa-lang* 琺瑯 enamels, and in the third month received orders for more of the same. In the eleventh month of +1754 Thang selected a vase with a rotating section in *yang-tshai* enamels.[125]

Contemporary Chinese texts described the manufacture of the colours. *Thao Shuo* (+1774) noted that colours for porcelain decoration needed to be ground and mixed very thoroughly, otherwise coarse, deeper blotches of colour would appear. Pigment formulae, arrived at empirically, were also extremely specific. Ten ounces (*liang* 兩) of materials were put into each mortar and ground by special artisans for an entire month. This was low-paid work, often done by the very old and the very young, the crippled and infirm. In a desperate effort to earn more, some workers worked two pestles simultaneously, or kept working till midnight for double pay.[126]

Ching-te-chen Thao Lu (+1815) recorded how overglaze decoration at Ching-te-chen was done by top-quality artisans working for the imperial factory, but also by a great number of small firms. They operated by purchasing fired porcelain blanks of all qualities, decorating them, and refiring them in small muffle kilns. Costs were therefore relatively low, and within the grasp of small family concerns. The shops selling these wares were called *hung-tien* 紅店 and they lined the streets of Ching-te-chen, concentrated on 'Porcelain Street' (*Tzhu-chhi Chieh* 瓷器街).[127]

After +1768 there was a decline in the standard of enamelled ware, due to reorganisation of supervision at the imperial kiln (see pp. 196–7 and 771–2), and dereliction of duty and corruption became widespread. It is possible that European techniques in preparing enamels were tried in the +19th century (see p. 639), and in the early +20th century a new palette of colours was introduced, along with many

[125] Fu Chen-Lun & Chen Li (1982), pp. 25–6, 36–44, 52, 57, 60–5; Chang Fa-Ying & Tiao Yün-Chan (1991), vol. 1, pp. 932–3, 936–7.
[126] *Thao Shuo*, ch. 1, pp. 7a–b. See also *Ching-te-chen Thao Lu*, ch. 1, p. 4b.
[127] *Ching-te-chen Thao Lu*, ch. 4, p. 7b.

other changes at Ching-te-chen. Around +1910 new, bright, easily usable colours were imported, first from France and later from Japan. Paper patterns, transfers and stamped decoration came in about the same time.[128]

OTHER *FAMILLE ROSE* COLOURS

As the accounts above show, the history of the adoption of translucent and opaque enamels in China (whether used on porcelain, glass or metal), from the late +1720s onwards, involved considerable interaction between European specialists and Chinese craftsmen. The gold-ruby enamel was certainly a non-Chinese effect, with a long history in Mediterranean and West Asian glass production, and then, later, in northern European ceramics and glass. The enamel colour was most probably introduced to China from Europe but, given the antiquity of the process, sources in the Near East, or even India, still cannot be discounted. However ruby-pink enamel was only one of three new enamel colours adopted for late Khang-Hsi porcelain, the other two being lead-arsenic white and lead-stannate yellow.

The association of opaque yellow and opaque white with translucent pink-red in the new Chinese overglaze enamel colours has led many writers to assume the entire *famille rose* palette to be a Western import.[129] There is good evidence to show, however, that both lead-stannate yellow and opaque lead arsenate white had already been used in China as glass colourants in Chinese cloisonné enamelling on metal, prior to their adoption in the +18th century for enamelling on porcelain. On Chinese cloisonné, use of lead-stannate yellow can be traced back to the +15th century,[130] and arsenic-white to the second quarter of the +17th century.[131] The presence of fluorine in this arsenic-white enamel, and its chemical make-up that is consistent with traditional Chinese cloisonné style, both suggest Chinese manufacture for the original enamel-glass.[132] There is also evidence for a combined use of lead-tin yellow with arsenic in a +15th-century Chinese yellow cloisonné enamel-glass, although how deliberate the presence of arsenic was in that case is difficult to say.[133] Those cloisonné compositions can be compared with Chinese overglaze porcelain enamels of the +18th century, analysed by Kingery and Vandiver (Table 132).[134]

This Table is interesting, not only for the obvious Chinese precedents for the use of lead stannate and lead arsenate in cloisonné enamelling prior to the early +18th

[128] Anon. (1959a), p. 286.

[129] Kingery & Vandiver (1985), p. 380, for example, write: 'The methods of preparation and the use of arsenic white, lead-tin yellow and gold ruby-red indicate that the basic technology [for the Chinese *famille rose* palette] arose from color decoration of European glass or enamels on metal, but were developed into a creative Chinese repertoire quite different from the European technology being used for porcelain decoration at the time.'

[130] Twilley (1995), p. 168, writes on an early fifteenth-century Chinese cloisonné enamel: 'Our diffraction data clearly show that the "opaque" yellow is pigmented by lead-tin yellow, however it should be noted that relatively little tin is present.'

[131] Henderson *et al.* (1989b), p. 142 and p. 137, table 1.

[132] *Ibid.*, p. 336.

[133] Biron & Quette (1997), p. 39.

[134] Kingery & Vandiver (1985), p. 375, table V.

Table 132 *Chinese cloisonné enamels and Ching-te-chen overglaze-white and overglaze-yellow enamels of the +18th century compared*

Date		PbO	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	CuO	CoO	MnO	SnO_2	Sb_2O_5	F	As_2O_5	Total
Yellow	*Enamels on metal*																	
+15th C	cloisonné [a]	57.8	35.8	0.2	0.2	-.-	0.03	-.-	6.2	0.6	0.02	0.0	0.0	0.4	-.-	-.-	-.-	101.3
+15th C	cloisonné [b]	48.3	36.2	0.5	1.2	0.0	0.75	0.4	5.45	1.8	0.2	0.02	0.02	3.2	0.0	0.2	0.14	98.4
+15th C	cloisonné [c]	52.4	35.8	0.2	0.4	0.04	0.6	0.6	4.95	0.2	0.1	0.0	0.01	2.4	0.05	0.0	1.0	98.8
+17th C	cloisonné [d]	47.3	31.0	0.8	1.1	0.05	2.6	0.1	5.7	6.0	0.0	0.0	0.0	2.3	0.0	n.s	0.0	97.0
Yellow	*Enamels on ceramic*																	
+16th C	*Fa hua* [e]	36.2	48.2	1.6	2.5	0.0	3.1	0.0	6.2	1.5	0.2	0.0	0.0	1.8	0.0	-.-	0.0	101.3
+18th C	Porcelain [f]	57.5	35.2	0.3	0.4	-.-	0.8	0.1	2.75	1.4	0.2	0.0	0.01	.9–2.8	0.0	-.-	0.0	98.7
White	*Enamels on metal*																	
+17th C	Cloisonné [g]	40.5	42.8	0.4	0.1	0.0	1.8	0.1	9.0	1.1	0.0	0.0	0.0	0.0	0.0	-.-	3.2	99.0
+18th C	Porcelain [h]	43.2	43.3	1.0	0.1	-.-	0.1	0.1	5.7	2.55	0.1	0.0	0.03	0.1	0.0	-.-	4.3	100.6

[a] Twilley (1995), p. 169, table 1.
[b] Biron & Quette (1997), p. 39.
[c] *Ibid.*
[d] Henderson *et al.* (1989b), p. 328.
[e] Wood *et al.* (1989), p. 180.
[f] Kingery & Vandiver (1985), p. 375.
[g] Henderson *et al.* (1989b), p. 329.
[h] Kingery & Vandiver (1985), p. 375.



Fig. 151 Yung-Cheng period garlic-mouth vase with robin's egg glaze together with Yung-Cheng garlic-mouth vase with flambé-red glaze

century, but also for the overall compositional similarities that are evident between Chinese metal enamels and Chinese porcelain enamels. The latter were used at Ching-te-chen in the new *famille rose* palette.

Arsenic Opacification in Chhing Dynasty Ching-te-chen Monochrome Glazes

This general similarity noted between Chinese cloisonné glass compositions and later Chhing overglaze enamels can also be seen in some low-firing monochrome glazes used on Ching-te-chen porcelains from the Yung-Cheng reign period onwards. A particularly good example is the *lu-chün* glaze 爐鈞釉, known in the West as the 'robin's egg' effect, a name that has been translated back into Chinese in a literal fashion as *chi-keng-niao tan yu* 知更鳥蛋釉. This glaze seems originally to have been developed as a low-firing version of Sung dynasty Chün ware 鈞窯, and the first

Table 133 *Comparisons with Chinese cloisonné and* famille rose *enamels*

	Na_2O	Al_2O_3	SiO_2	K_2O	Fe_2O_3	CoO	CuO	As_2O_3	PbO	CaO	F	Total
Blue *lu-chün* glaze (blue area)	2.4	0.8	43.8	7.0	0.4	0.1	2.9	2.6	39.6	-.-	-.-	99.6
Opaque white cloisonné												98.9
Enamel, 2nd quarter 17th C.[a]	1.1	0.4	42.8	9.0	0.1	0.0	0.0	3.2	40.5	1.8	present	
Famille rose white enamel[b]	2.5	1.0	43.3	5.7	0.1	0.0	0.07	4.3	43.2	0.14	-.-	100.5

[a] Henderson *et al.* (1990), pp. 338–9, table III.
[b] Kingery & Vandiver (1985), p. 375, table V.

Chhing dynasty applications of the technique were often of imperial quality. For these low-firing versions of Sung dynasty Chün wares, gold-pink enamels seem to have been applied to arsenic-opacified turquoise-blue-green enamel grounds.

Many examples produced small reddish streaks on the blue-green ground, but in some cases interaction between the two glazes during firing created millions of small rings of rose-red on the turquoise background. This latter result was probably unexpected, and seems to have been caused by bubbles in the glazes bursting during firing. However the effect was soon used at Ching-te-chen to decorate small and complex porcelain objects, and formal references to Sung Chün wares were dropped. Soon versions appeared with blue rather than red top-glazes, and these too showed the ring-effect, again often modified to streaks by slightly higher-firing temperatures. A single example of this latter type was analysed recently by the authors, and gave the results shown in Table 133.[135]

THE *FAMILLE ROSE* FLUX-BALANCE

In Table 133, the cloisonné glass, the overglaze porcelain enamel, and the porcelain monochrome glaze show both lead-arsenate opacification and a flux-balance that is lead-alkali in its nature, rather than simply lead-rich. Traditional *famille verte* enamels had their compositional roots in the plain, lead silicate, +12th/+13th-century Tzhu-chou 磁州 enamels of north China. The *famille rose* enamels, by contrast, were essentially lead-alkali silicates of Chinese cloisonné style, with significant levels of potassium oxide. In practice this gave the enamels a more sophisticated and 'waxen' quality, and this development has some parallels to the changes that occurred from lime- to lime-alkali stoneware glazes, at a much earlier date in China. As Henderson *et al.* have pointed out, this compositional development was heralded in the earlier Khang-Hsi reign period by use of cobalt-blue overglaze

[135] Wood *et al.* (2002), p. 350, Table 5. The blue pigment used in the *lu-chün* glazes is, unusually for China, rich in nickel and in iron. This is a type of cobalt ore more familiar from Europe (for example, from Silesia in Germany), or from Iran (for example, from Qamsar), so it may have been an imported material.

Table 134 *Ching-te-chen overglaze enamels of the Khang-Hsi reign period: the* famille verte *style*[a]

	PbO	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	CuO	CoO	MnO	Cl	Total
Blue	47.8	42.15	0.4	0.3	-.-	0.9	0.04	6.2	0.45	0.15	0.2	-.-	1.6	100.2
Bright green	62.7	31.5	1.0	1.0	-.-	0.4	0.05	0.1	0.06	3.1	-.-	-.-	0.0	99.9
Dark green	58.7	32.3	1.0	0.3	0.01	0.6	0.1	0.4	0.3	6.0	-.-	-.-	0.4	100.1
Olive green	66.2	29.0	0.6	1.15	0.02	0.14	0.02	0.2	0.1	2.1	-.-	-.-	-.-	99.5
Coral red	41.4	24.0	5.0	22.8	0.0	2.4	0.1	0.25	0.3	0.13	-.-	-.-	-.-	96.4
Light purple-grey	69.5	29.0	0.8	0.05	-.-	0.04	0.0	0.2	0.1	0.1	-.-	0.2	-.-	100.0

[a] Kingery & Vandiver (1985), p. 370, Table II.

enamel in the *famille verte* palette, a colour that stands out from its contemporaries by reason of its unusual lead-alkali base (Table 134).

THE KHANG-HSI PERIOD OVERGLAZE-BLUE

Cobalt-blue lead glazes had been used, albeit sparingly, on porcelains at Ching-te-chen as early as the Hsüan-Te reign period.[136] After the mid-Ming period the colour then seems to disappear from the enamellers' repertoire, before reappearing in the mid +17th century.[137] Père d'Entrecolles' notes that the Khang-Hsi period '*violet*' enamel was a blue glass used for enamelling with metal, and the material came variously from Canton or Peking. Unlike other Khang-Hsi enamels, which were prepared from raw materials and used unfritted, the blue enamel was a true coloured glass that was ground under water in a porcelain mortar and then painted on to the porcelain with water and a little animal glue.[138] Henderson *et al.* see the use of this metal-enamelling glass in the Khang-Hsi reign period as a possible precedent for the adoption of other Chinese cloisonné-related colours in the +1720s:[139]

> The analyses do show that three of the four colors adopted at Jingdezhen [Ching-te-chen] for the *famille rose* palette were already in use in China as cloisonné enamels in the 17th century AD, so the secrets of their manufacture were not necessarily imported from Europe for porcelain enamelling in the 18th century AD. There is also good first-hand evidence for the use of metal-enamel glass at Jingdezhen at the time that the *famille rose* colors appeared.

[136] See Liu Hsin-Yüan (1989) and an excavated dice bowl with mottled blue glaze, no. 94, pp. 270–1.

[137] Kilburn (1981), no.158, p. 180, and colour pl. on p. 137, illustrates a small plate with overglaze-blue enamel dating to the Chhung-Chen reign period. He suggests the piece may have been made in Fukien province, and stresses the atypical use of blue enamel as being very rare before the early Khang-Hsi reign period. Butler (1985) illustrates a small dish decorated with blue enamel, that he dates to the early +17th century, on pp. 51–2, pl. 27. Butler *et al.* (1990) include a plate with tiger design in blue enamel on p. 65, pl. 27, and date it to the Chhung-Chen reign period.

[138] Tichane (1983), pp. 123–4, translation of Père d'Entrecolles' letter of +1722.

[139] Henderson *et al.* (1989b), pp. 342–3.

This strongly suggests that Chinese craftsmen were able to draw on a well-established Chinese cloisonné enamel tradition for many aspects of their new opaque enamel palette. These translucent and opaque colours transformed the appearance of Ching-te-chen porcelain in the Yung-Cheng and Chhien-Lung reign periods, and remain the basis of the standard Chinese overglaze enamel style today.

HIGH-FIRING COLOURS: COPPER, IRON AND COBALT

The varifold uses of iron and copper as glaze colours have been explored in Section 5. Here we shall consider use of the minerals as an in- or underglaze pigments, together with a longer exploration of the mineral cobalt-blue.

IRON-BROWN AND COPPER-RED

PAINTING AND LIME-GLAZED WARES

The long absence of successful fired painted designs on Chinese ceramics that occurred after dramatic slip painting of the earlier Neolithic period (see pp. 609–10), seems initially to have been caused by a fashion for greywares and blackwares in the later Neolithic. This tended to bring all surface ornament to the same tone, losing contrast in painted designs and causing the technique to fall from use. The arrival of ash-based lime glazes in the Bronze Age hardly improved the situation because of their poor performance with painted oxides, which tended to spread within the molten glazes, to give blurred and diffused results. Some spectacular (if blurred) attempts at iron painting with lime glazes were made early in the Southern Dynasties, but the style was not pursued.[140] Yüeh wares 越窯 from Chekiang province too, perhaps the most prestigious and historically important of southern lime-glazed ceramics, occasionally featured underglaze iron painting as part of their decorative repertoire, but the painted wares were in a minority.

THE THANG DYNASTY: CHHIUNG-LAI 邛崍窯 AND CHHANG-SHA 長沙窯 KILNS

It was during the Thang dynasty that new strides were made in fired, painted decoration on ceramics, using all three colours discussed here: cobalt, copper and iron. At both the Chhiung-lai kilns 邛崍窯 in Szechuan province and Chhang-sha kilns 長沙窯 in Hunan province, copper-tin mixtures provided greens and bluish-greens when added to standard stoneware glazes, while additions of iron-manganese minerals gave purplish-browns within the same glaze-bases. Extra iron oxide was also added to clay and ash glazes at both kiln sites for dark amber-brown effects. These various coloured glazes were painted, dotted and trailed above or beneath ordinary lime glazes, often in detailed, if somewhat blurred, designs. Most Chhiung-lai and

[140] A jar dating to the Southern Dynasties (+5th to +6th centuries) in the Nanking Museum is in Anon. (1994a), pp. 104–5.

Chhang-sha glazes were fired in oxidising-to-neutral atmospheres, typically to temperatures between 1,200° to 1,240°C.[141]

The Chhiung-lai kilns may have been the first to break with the universal iron-titania grey-green glazes of southern China, as sherds with simple dotted patterns in iron-brown and copper-green, and dating from the Sui dynasty, have been excavated from the Wa-yao-shan kiln 瓦窯山窯, and from Chin-ma 金馬 at nearby Kuan-hsien 灌縣.[142] Nonetheless the use of copper to give green effects in oxidised stoneware glazes had already been tried in northern China. A few rare Northern Chhi dynasty stonewares were decorated with copper-green stripes, such as the green-and-white bottle excavated from the tomb of Fan Tshui 範粹 (*d.* +575) at An-yang 安陽 (see also p. 147 and Fig. 35). Straw-coloured earthenwares with vertical green glaze-stripes are known from northern burials at this time, so it seems possible that lead-glazed wares served as models for these early experiments with copper in high-temperature glazes.[143] As copper had been associated with earthenware glazes since their origins in the Near East in the –6th millennium, and iron had been the sole major glaze colourant in high-temperature glazes since the Shang dynasty, the second half of the +6th century seems to have been the point at which these two major colourant and glaze traditions at last combined in China.

Yellow-white glazed wares continued to be made at Chhiung-lai in the Thang dynasty, decorated with iron and copper minerals. Onglaze decorated ware was slipped, glazed and painted, and fired at 1,200°C. Underglaze decorated ware was slipped, painted and fired at 1,250°C. A sherd of a cover found at Chhiung-lai in +1986 had a date equivalent to +669, and was decorated in underglaze iron with pearls, threads and lotus-petal designs. Another item decorated in underglaze-iron-brown was dated to +746, and had Taoist figural decoration. A third piece dated +836 bore Taoist designs of waves, stars and Chinese characters for water, earth, fire and wood. Those ceramics from Szechuan province resembled Chhang-sha wares in five ways. Both were folk wares, used slip, pioneered both overglaze and underglaze painting, used low-quality local raw materials, and were the first to employ copper-red.[144]

White-slipped stonewares with splashes and stripes of a copper-green glaze on clear-glazed grounds became a popular style at many kilns in north China in the Thang dynasty,[145] and in southern China too lively dippings, brushings and trailings of green glazes on white glaze-grounds were practised at both Chhang-sha and at Chhiung-lai. These broad green-on-white effects were popular with Western markets

[141] Zhang Fukang (1985), pp. 31–2; Zhang Fukang (1987), pp. 83–92; Zhang Fukang (1989), pp. 60–5.
[142] Chen Liqiong (1986), p. 322.
[143] For an earthenware version, see a Northern Chhi dynasty jar with square lugs unearthed in Honan province and now in the Palace Museum, Peking: in Yang Gen *et al.* (1985), p. 85, pl. 82.
[144] Chhen Li-Chhiung (1992), pp. 470–1.
[145] For example, Tzu-po 淄博 in Shantung province, Hughes-Stanton & Kerr (1980), pl. 431; Kuan-thai 觀台 in Hopei province, Wood (1996), p. 60; Chiao-chheng 交城 in Shansi province, Feng Xianming (1985), p. 45: Yao-chou 耀州 in Shensi province, Anon. 1992a (Huang-pao kiln 黃堡窯), unpaginated; and at Yen-tshun 閻村, near Hui-hsien 煇縣 in Honan province, McElney (1993), p. 78.



Fig. 152 Chhang-sha dish with copper painting

and in Mesopotamia and Egypt, green-splashed whitewares were also produced locally, in a style reminiscent of imported Chinese stonewares, but using tin-oxide-opacified earthenware glazes rather than the original high-temperature compositions. As Chinese wares of this style have been found in Iraq in a context dated to +803, at about the time that ceramics in this style first appear in the Near East, a Chinese influence on Near Eastern ceramic design seems probable.[146]

The manufacture of good-quality wares decorated under the glaze at Chhang-shha, and of their lower-quality companion wares from Chhiung-lai, marked the use of copper-green stoneware glazes for quite detailed ornament. Fine glaze brushwork with copper-rich glazes, and the building of detailed patterns from fine copper-green dots, were both practised at both kilns and these southern wares show the most successful use in China of fired-on painted ornament since the Neolithic period.

Chhang-sha specialised in the manufacture of painted pots with jaunty designs of birds, flowers and splashed patterns like batik-dyed cloth. Inscriptions were common, some poetic in nature but others containing dates which help to periodise the ware. To date, the earliest example was a modelling mould for a jar's ear inscribed with the date 'the third year of Yüan-Ho 元和三年' (+808), and the latest

[146] Fleming *et al.* (1992), p. 217. See also pp. 732–5 of this book.

Table 135 *Analyses of Chhang-sha and Chhiung-lai glazes: late Thang dynasty to Five Dynasties*

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	CuO	SnO_2	PbO	Total
Chhang-sha glazes[a]														
Transparent yellow-white	62.1	12.3	0.9	1.4	14.9	2.25	2.0	0.1	0.5	1.3	-.-	-.-	-.-	97.8
Opaque yellow-white	59.9	9.2	0.8	0.85	16.95	3.4	2.1	0.2	0.8	3.0	-.-	-.-	-.-	97.2
Painted colour: opaque green	57.4	8.7	0.65	0.9	18.5	2.6	1.8	0.25	0.7	2.3	3.0	0.6	0.15	97.6
Painted colour: brown	57.0	12.0	0.9	5.15	15.7	2.4	1.7	0.2	3.3	-.-	0.04	-.-	-.-	98.4
Painted colour: dark brown	58.8	11.25	-.-	10.7	11.75	2.4	2.4	0.2	0.3	-.-	-.-	-.-	-.-	97.8
Chhiung-lai glazes[b]														
Opaque-turquoise	57.4	9.1	0.7	2.6	17.6	4.0	2.0	0.7	0.35	2.3	3.4			100.15
Yellow transparent	59.9	10.8	0.7	3.0	16.5	4.5	1.4	0.4	0.4	2.3	0.1			100
Brown-green	59.9	10.1	0.7	2.6	17.5	4.3	1.5	0.3	0.5	1.9	1.5			100.8

[a] Zhang Fukang (1987), p. 90, table 2.
[b] Zhang Fukang (1989), p. 64, table 2.

an oblong pillow with inscription 'the sixth year of Chen-Ming 貞明六年' (+920). General observations based on the comparison of Chhang-sha finds from waster heaps with finds from dated tombs indicate that production of characteristic wares with underglaze decoration began in the early Thang dynasty and came to an end during the Five Dynasties period (Table 135).[147]

Another decorative technique employing iron pigment should be mentioned briefly here, namely the straightforward method of spotting low-iron celadon glazes with super-saturated iron dots. This simple decoration was used on celadon glazes in Chekiang province in the $+4^{th}$ to $+5^{th}$ centuries, and it only reappeared in the $+12^{th}$ to $+13^{th}$ centuries at the Lung-chhüan kilns 龍泉窯 in Chekiang province and at Hsi-tshun kilns 西村窯 in Kuangtung province.[148]

COPPER PIGMENTS ON CHÜN GLAZES

The copper pigments used on Chün glazes seem to have been high in tin oxide, so were probably made from oxidised bronze,[149] producing effects that gave swirling red or purple patterns against the lavender-blue ground. The copper was brushed on to the dry glazes and fired with the main glaze to full heat.

[147] Timothy See-Yiu Lam (1990), p. 37.
[148] Vainker (1991), p. 55.
[149] See the correlations between Cu and Sn in Yang Wenxian's & Wang Yuxi's analyses of Chün wares (1986), p. 205, table 1.

Table 136 *Jung-hsien* chhing-pai, *copper-green and copper-red glazes*[a]

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	P_2O_5	CuO	Total
Glazes												
Jung-hsien *chhing-pai*	63.3	14.3	0.05	1.0	15.3	1.45	3.5	0.07	0.3	1.05	-.-	100.3
Jung-hsien green	58.7	14.1	0.07	1.3	15.4	1.9	3.6	0.2	0.55	1.2	2.9	99.9
Jung-hsien red	64.0	14.3	0.1	1.2	12.2	2.0	3.7	0.4	0.1	0.5	0.7	99.2
Bodies												
Jung-hsien *chhing-pai*	70.1	22.2	0.03	1.2	0.5	0.7	5.05	0.12	0.14	0.07		100.1
Jung-hsien green	70.0	23.7	0.02	1.1	0.1	0.6	4.9	0.12	0.14	0.05		100.7

[a] Zhang Fukang *et al.* (1992a), p. 376, table 1 and poster-paper.

On some examples, differences in thickness, and some variations in kiln atmosphere, have resulted in copper-colours that vary in hue. They range from black to green, to purple and then to red, manifesting almost the full suite of colours possible from copper and its oxides. More often the brushmarks are a reddish-purple, most probably from a merging of copper-red with glass-emulsion blue. In some ways the dynamism and the subtle placement of the hazy copper-red brush marks applied to Chün wares represent a continuation of decorative principles first practised with Thang dynasty 'splashed' blackwares.

COPPER PIGMENTS AT JUNG-HSIEN 容縣

In the Sung period Jung-hsien potters occasionally added copper oxide to their *chhing-pai* 青白 glazes to produce green oxidised versions of Yao-chou 耀州 stonewares, made some 2,400 kilometres to the north in Shensi province. Sherds of Northern Sung Yao-chou celadon originals with their local equivalents have been found at Jung-hsien sites, and these show that careful and deliberate imitation of the northern wares had been practised with porcelain materials in Kuangsi province.

Further evidence for the Jung-hsien potters' ingenuity is seen in the low levels of copper oxide used for the reduction-fired Jung-hsien copper-red glazes (Table 136). These are significant, as good copper-red colours need far less copper in their recipes than oxidised copper-green glazes.[150] This fine technical point was obviously appreciated by the Jung-hsien potters, and its use at this site suggests that the 'Jung-hsien red' of the Northern Sung dynasty may be a deliberate rather than an accidental effect, and perhaps the first intentional use of the copper-red glaze on Chinese porcelain.

[150] See Tichane (1985), pp. 77–85 ('Things That Go Wrong'), for a discussion of the effects that can spoil good copper-red colours.

COPPER PIGMENTS AT CHING-TE-CHEN 景德鎮

A single Yuan dynasty underglaze-red pigment (from a small cubic porcelain bottle with 'beaded' relief ornament, and a late *chhing-pai*-type glaze) has been analysed by the non-destructive process of air-path X-ray fluorescence and proved to have been a mixture of copper with a considerable amount of iron.[151] Later +14th-century underglaze-copper-red pigments at Ching-te-chen tended to be copper-arsenic mixtures, perhaps derived from copper-arsenic sulphide ores.[152] In the early Chhing dynasty calcium carbonate seems to have been added to Ching-te-chen underglaze-red pigments,[153] and Vogt also found the +1882 underglaze-red pigment used at Ching-te-chen was a copper-lime mixture.[154] The reason for this carbonate addition may well have been to make the copper-red pigment locally more fusible (and therefore brighter-looking) in the narrowly defined area of its painting, while the use of stiffer (lower-calcia) porcelain glazes prevented too much diffusion of the copper into the surrounding glazes.[155]

COBALT-BLUE

COBALT IN CHINESE CERAMICS

The intensely blue colours that are possible in glazes and glasses through small additions of cobalt oxide were used intermittently and in a minor way by Chinese potters and glass-makers between the Warring States period and the early +14th century. At that point, cobalt ores were adopted by Ching-te-chen porcelain-makers as underglaze-blue pigments. That technology proved so effective that it was used for fine imperial wares, large and elaborate export dishes and jars, as well as volumes of cheaper 'folk' porcelains made both for home and abroad.[156] Experience gained from painting in underglaze-cobalt-blue pigments in the first half of the +14th century laid the foundations for the huge and influential blue-and white industry that developed at Ching-te-chen and which still flourishes today.

Besides its prime use as an underglaze-blue pigment for decorating porcelain in south China, cobalt oxide has also been used in Chinese lead-, lead-baria and lead-potassia-fluxed earthenware glazes,[157] in overglaze porcelain enamels,[158] in cloisonné enamels[159] and also in later Chinese coloured glasses.[160] As a silicate

[151] Wood (1993), p. 52.
[152] Tichane (1985), p. 50; Wood (1993), p. 53.
[153] Wood (1993), pp. 56–7.
[154] Vogt (1900), pp. 594–6.
[155] Wood (1999), p. 182. Hermann Seger used a similar approach at Berlin in the later +19th century, see Seger (1902d), p. 745.
[156] See Shih Ching-fei (2001), pp. 60–98. Yuan wares similar to those found at excavated kilns have been excavated in, for example, South-east Asia in large quantities, see Liu Xinyuan (1992), p. 29.
[157] Brill *et al.* (1991a); Li Zhiyan & Zhang Fukang (1986); Li Guozhen *et al.* (1986); Wood *et al.* (1989).
[158] Kingery & Vandiver (1985); Henderson *et al.* (1989b).
[159] Henderson *et al.* (1989b); Twilley (1995); Biron & Quette (1997).
[160] Shi Meiguang & Zhou Fuzheng (1999), pp. 102–5.

colourant, cobalt oxide is the most powerful in the glass- and glaze-makers repertoire, and can give noticeable blues in glasses at levels as low as 0.005%.[161] As glazes tend to be much thinner than glasses they need more cobalt to achieve comparable tones, typically 0.1 to 0.5% CoO. However cobalt oxide levels as high as 1.0% CoO are occasionally found in Chinese ceramic glazes, such as the deep- and dark-blue lead glazes applied to some Thang dynasty *san-tshai* 三彩 wares.[162]

In their natural states, cobalt ores tend to contain substantial amounts of additional transition elements such as iron, copper, nickel and manganese, as well as volatile non-colourants such as arsenic, sulphur and water.[163] Fired in reduction, and in high-temperature glazes, these colourant 'impurities' modify the natural harshness of pure cobalt oxide, and allow fine blues to develop. In oxidised firings and in high-lead glazes these same associated colouring elements diminish or destroy the cobalt-blue effects, giving various browns, greys and blacks. This means that lead glazes and oxidised high-temperature glazes need relatively pure sources of cobalt, while more contaminated cobalt ores work well as underglaze-blue pigments fired in reduction. In its purest state, cobalt oxide is generally insensitive to firing atmospheres and gives strong blues in all conditions, and within most types of historical glaze and glass.[164]

So far, the earliest documented example for the use of cobalt oxide in Chinese ceramics occurs in glazed *faience* beads from the period -4^{th} to -1^{st} centuries.[165] The colour reappears and is used in a limited manner during the $+8^{th}$ century for *san-tshai* glazes at kiln-complexes such as Kung-hsien 鞏縣 and Huang-pao 黃堡.[166] With the decline of *san-tshai* wares in the later Thang dynasty, cobalt ores were used as high-temperature underglaze-blue pigments on some rare northern white stonewares, probably made at kilns near to Kung-hsien in Honan province.[167] Sporadic cases of cobalt usage occur in the Sung dynasty, but the technology saw its most important revival in south China in the late +1320s at kilns near to Ching-te-chen in Chiangsi province.[168] Ching-te-chen porcelains decorated with painting in underglaze-blue were exported virtually from the start, and soon became a staple of China's ceramic industry.

Nonetheless, and despite cobalt oxide's great importance in China's later ceramic history, its use in the country is a relatively recent phenomenon when considered both against the history of Chinese ceramics itself, and the larger

[161] 'Cobalt has an amazingly high colouring power. As little as one part in 500,000 produces a recognisable tint, while one part in 5,000 produces a blue sufficiently intense for most ware.' Scholes (1946), p. 184.

[162] Li Zhiyan & Zhang Fukang (1986), p. 69, table 1; Li Guozhen *et al.* (1986), p. 78, table 2.

[163] More than 70 cobalt minerals or ores have been described. See Andrews (1962), pp. 6–12, for a useful survey.

[164] Glass or glaze matrices rich in magnesium oxide or zinc oxide may change the usual blue colours from cobalt oxide to pink and green respectively, but these compositions do not appear in historical glasses or glazes. See Weyl (1959), pp. 171–99, for a comprehensive account of cobalt's behaviour in silicate melts, and Bamford (1977), pp. 42–4, for an account of cobalt's optical absorption characteristics in glass.

[165] Brill *et al.* (1991a), pp. 49–53, table 1.

[166] Li Zhiyan & Zhang Fukang (1986), p. 69, table 1; Li Guozhen *et al.* (1986), p. 78, table 2.

[167] Zhang Zhigang *et al.* (1985); Luo Zongzhen *et al.* (1986), and Chen Yaocheng *et al.* (1995).

[168] Lui Xinyuan (1992), pp. 37–9. For a catalogue of the small number of Sung dynasty pieces known that bear decoration in underglaze-cobalt-blue, see Harrison-Hall (2001), pp. 53–4.

background of world ceramics and glass. Cobalt-blue glasses have been traced to Iraq in the –21st century,[169] and cobalt appears in some blue pigments on unglazed Egyptian ceramics from the middle of the XVIIIth dynasty until the XXth dynasty.[170] Cobalt oxide therefore made its first appearance in silicate pyrotechnology in Mesopotamian soda-lime glass some eighteen centuries before it was used in Chinese bead glazes. This places the use of cobalt oxide in Chinese glazes to about the same time as, or slightly later than, copper oxide. Copper oxide was China's other prime 'non-adventitious' glaze-colouring oxide.

This makes the succession of colourant usage in Chinese glazes echo the metals' abundance in igneous rocks, that is: Fe 500, Ti 44, Mn 10, Cu 0.7 and Co 0.4.[171] In chronology this amounts to iron, titanium and manganese oxides occurring naturally in the clays and ashes used to make Shang dynasty stoneware glazes, with copper and cobalt being first used in Warring States bead glazes. This is a very different pattern from that established in West Asia, where oxides of copper, cobalt, antimony and tin appear in glasses and glazes practically from their inception. Iron oxides, the prime glaze colourants in Chinese ceramics, played only a very minor role in Near Eastern glass and glaze pigments.

The first examples of cobalt colours excavated in China seem to be imported glasses, such as a blue-and-white eye-bead found in a royal tomb in Honan province (Table 137), and dated to the Spring and Autumn period (–770 to –476).[172] This turquoise bead with blue-and-white 'eyes' proved to be of the soda-lime type, and free from lead and barium oxides. The cobalt colourant was of the high-iron low-manganese variety, and the white areas of the glass contained both arsenic and antimony. All these compositional factors suggest that the bead was imported to China from the Near East or Central Asia, and was of a style later imitated in China with the country's very distinctive lead- and barium-rich glasses.[173]

[169] 'The earliest fully documented use of cobalt should be in a blue glass from Iraq, in a working piece from Eridu dated to the 21st C. BC.' Kaczmarczyk (1986), p. 373. Moorey (1994), p. 191, describes this as: 'Perhaps the most famous single piece of raw glass from Mesopotamia . . .' and notes that the circumstances of its find would date it to the dynasty of Akkad or the early Ur III period. (Akkadian is –2,350 to –2,100, Ur III is –2,100 to –2,000). See also Henderson (1985), pp. 278–81, for a review of later uses of cobalt oxide as a glass colourant.

[170] Spencer (1997), p. 65, fig. 4 (XVIII dynasty –1,570 to –1,293; XX dynasty –1,212 to –1,070). See also Riederer (1974), pp. 104–106, and Noll (1981), where the cold blue colour is identified as a cobalt spinel, i.e. a cobalt aluminate. This raises the issue of the difference between the colours of cobalt minerals (which are sometimes, but not always, blue) and the effects of dissolved cobalt ions in historical silicate glasses and glazes. In the case of cobalt aluminate, used as a fired pigment on wares of the –2nd millennium in Egypt, the blue is noticeably cold in tone, while the same raw material dissolved in an Egyptian glass or glaze will be a 'hot' royal blue, with a high component of red in its colour.

[171] Kaye & Laby (1957), p. 110 (expressed as 10^{-4} g/g).

[172] Zhang Fukang *et al.* (1986), pp. 92–3 and fig. B11–1, Plate IV. Natalie Venclová (1983), p. 14, notes: 'Yellow or turquoise beads with stratified blue-white eyes from the fourth to the sixth century B.C. have been found . . . The finds cover a vast area from the Mediterranean north to Saxony and Poland. In the west they are found as far as Britain; in the east they are known in the northern area of the Black Sea.'

[173] Wood *et al.* (1999), p. 29, note 33; p. 174, note 48, tables 1 and 2.

Table 137 *Glass eye-bead from a royal tomb dating to the Spring and Autumn period in Honan province*[a]

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	CoO	Sb	As	Total
Glass eye-bead	-.-	-.-	-.-	0.65	9.42	0.4	0.52	10.94	detected	detected	detected	21.85

[a] Zhang Fukang *et al.* (1986), p. 94, table 3, and p. 97.

COBALT OXIDE COLOURANTS IN ANCIENT NEAR EASTERN GLASS

It is often suggested that cobalts from West Asia were used in Chinese ceramics, so the cobalt resources of the Near East have some relevance to this subject. Two separate sites of origin have been proposed for Near Eastern cobalt ores: cobalt-bearing alums from the evaporites of ancient Egyptian lakes, and another source, as yet unidentified, but most probably in Iran. The first type seems confined to Egyptian ceramics and glass of the New Kingdom period (–1,570 to –1,070), and to some contemporary blue Mycenaean glasses of Crete. All other Near Eastern glasses and ceramics appear to have used the second type of cobalt ore, which correspond in character to the blue-and-white bead found in China. Alexander Kaczmarczyk has investigated the first source, and explains its use and occurrence as follows:[174]

Chemical analyses of Egyptian blue pigments of the second millennium BC have established that those containing cobalt invariably contain elevated concentrations of aluminium, magnesium, manganese, iron, nickel and zinc . . . The alums were deposited when ancient lakes evaporated . . . If the alum is dissolved in water and the solution rendered mildly alkaline (with natron, plant ash or ammonia), the transition metals precipitate as hydroxides and oxides leaving the sulphates behind. Drying and heating the precipitate yields a blue mixture consisting of aluminates and oxides with a much higher pigment content.

Kaczmarczyk calculates that a typical refined cobalt-bearing alum would give a pigment containing about 5% CoO, together with substantial amounts of aluminium, manganese, iron, nickel and zinc.[175] He suggests, however, that:[176]

Whereas the Dakhla and Kharga oases are the most probable sources of the cobalt used in Egypt during the New Kingdom (16th–11th century BC), Iran must have provided the purer pigment employed after the 7th century BC . . . For centuries Iran has been famous for its manganese-free arseno-sulphide ores, which continued to be employed in Persian blue-and-white ceramics into the 20th C.

[174] Kaczmarczyk (1986), pp. 369–73. However Shortland (2000), p. 83, believes that such processing may have been unnecessary as: 'The results from the present work . . . seem to indicate that the alum does not need to be concentrated in any way to give the level of colorants seen in the glasses.' Kaczmarczyk (1986), p. 374, notes that cobalt of this unusual type also appears in Mycenaean (that is Cretan) glass artefacts, although he reserves judgement on a possible Egyptian source for this blue until more data appear.

[175] *Ibid.*, p. 373.

[176] *Ibid.*



Fig. 153 Persian dish decorated with cobalt-blue, +16th to +17th centuries

Kaczmarczyk's ideas on the alum sources for Egyptian cobalt (particularly from the Kharga oasis) have been supported by recent work at Oxford by Andrew Shortland, who found:[177]

a strong resemblance . . . between the chemistry of the cobalt used in the vitreous materials and glasses [from Amarna in Egypt] and that of the cobalt-bearing alums of the Kharga Oasis. Given the certainty that the Oasis was worked in antiquity, it is reasonable to assume that the pink colour of some of the alums would have come to the notice of some of the miners and that this alum was consequently used as the cobalt colorant in the vitreous materials at Armana.

[177] Shortland (2000), p. 49.

PERSIAN COBALT

The second prime source of cobalt pigments in West Asia, the Persian cobalts referred to by Kaczmarczyk, have been described by Kleinmann in a study made of blue painted tin-glazed ceramics from Samarra in Iraq (+9th century) and of underglaze-blue decorated faience from Persia itself. Kleinmann found blue spinel colourants in the cobalt painting on both wares and notes:[178]

Undoubtedly the Co-NiFe spinels in the pigments derive from Co-Ni-minerals, probably some of the numerous Co- Ni- or Co-Ni-arsenides, sulphides or arseno-sulphides. Their Co-Ni-Fe contents vary as much as in the spinels.

Kleinmann suggests that the cobalt used in the Mesopotamian and Persian ceramics probably came from the small village of Qamsar (or Khamsar) 35 kilometres south-west from Kashan in Central Iran, where the deposits consist of:[179]

1–10 metre thick magnetite vein interrupting a dolomitic limestone which contains some Cu-ores with secondary Cu- and Co-minerals like erythrite ($Co_3(AsO_4)_2 \cdot 8H_2O$), bieberite ($CoSO_4 \cdot 7H_2O$) and asbolane (a mixture of MnO_2 and heterogenite CoOOH) beside Ni-sulphide, probably a member of the linneite group (spinel $(Co,Ni,Fe)_3S_4$). . . Linneite within magnetite would fit Abu'l Qasim's description . . . He also mentions the 'the red and deadly poisonous kind on the outside of the stones' (=erythrite or bieberite).

The description by Abu'l Qasim was a treatise on tiles and other ceramics, written in AH700/+1301. Abu'l Qasim was a member of a prominent potter family at Kashan, and a Mongol court historian at Tabriz.[180] His text provided a very complete description of processes for forming, painting and firing ceramics in Persia in the +13th century. About cobalt it reported:[181]

The stone *lajvard*, that the craftsmen call *sulaimani*, its source is the village of Qamsar in the mountains round Kashan, and the people there claim it was discovered by the prophet Sulaiman. It is like white silver shining in a sheath of hard black stone. From it comes the *lajvard* colour, like that of *lajvard*-coloured glaze.

Kleinmann proposes a complex roasting and fritting operation to prepare these raw ores for ceramic use. This was deemed necessary because:[182]

Co-minerals like sulphides or arsenides will give only a light blue shadow when heated directly within a glaze while remaining undissolved.

This last idea has been questioned on the grounds that the glaze firing itself could have played a similar spinel-creating role for the raw ores, although preliminary roasting may well have been useful for the alternative purpose of driving arsenic

[178] Kleinmann (1991), p. 334.
[179] *Ibid.*
[180] Watson (1985), pp. 31–2.
[181] In Persian, the *sang-i lajvard* means lapis lazuli, though here the term must be used for cobalt. Cobalt was used as part of the composition of fake gemstones imitating lapis lazuli. For a description and translation of the text, see Allan (1973), pp. 112, 116, 120.
[182] Kleinmann (1991), p. 336.

and sulphur from the unprocessed materials.[183] It is also important to note that most blue effects produced by painted cobalt pigments will contain cobalt in both mineral (that is crystalline) and in solution forms (i.e. cobalt ions). The latter case is where the cobalt has dissolved and diffused within the glaze, and is usually the dominant state.

The complexity of the cobalt-bearing geology at Qamsar, however, makes attribution of particular cobalt pigments used in ancient ceramics and glasses to the mines near Kashan far from straightforward. The Qamsar deposits include cobalts that are high in iron, high in nickel, high in copper, and high in manganese. These are essentially the four main types of cobalt used in historical ceramics, apart from the special case of the Egyptian New Kingdom and the Mycenaean cobalts, which contain zinc. In fact many deposits of cobalt world-wide have high-iron and high-manganese cobalt ores in association. That point was made by James Watt in his important study of cobalt in Chinese ceramics, published in +1979. Writing on earlier investigations into the origins of cobalt in Chinese ceramics, Watt notes that:[184]

> Discussion of the results of these experiments have so far been based on the assumption that all native Chinese cobalt ores contain manganese as an impurity, and conversely, that the absence of manganese in the cobalt ores used indicates that the ore was imported.

Watt demonstrates the fallibility of this assumption and cites numerous low-manganese sources for Chinese cobalt.

COBALT-BEARING GLASS FROM CHHANG-SHA

Returning to cobalt-containing artefacts found in China, slightly later examples of dark-blue cobalt-containing glass beads have been excavated in Hunan, Kuang-tung and Kuangsi provinces, usually in Western Han dynasty contexts. These beads contained elevated manganese oxide levels, and potassium oxide levels of about 15%.[185] Their compositions correspond well to glasses of the same period from Arikamedu in India, which can also show substantial iron and manganese levels with traces of cobalt, and elevated contents of potassium oxide. It seems possible therefore that this blue glass was imported to China from India, or from other sites in South-east Asia, although the source of the cobalt used by the glass-makers is unknown.[186] Another example of a glass bead, from a Chhang-sha excavation, contained copper in addition to the cobalt+manganese colourants, to give a greenish

[183] Pers. comm. Sarah Paynter, Research Laboratory for Archaeology and the History of Art, Oxford. Roasting was later a standard procedure in the preparation of Saxon arsenical-cobalts. See Taylor (1977), pp. 8–13, for a full account.

[184] Watt (1979), pp. 64–5.

[185] Shi Meiguang *et al.* (1987), p. 18, table 2; Zhang Fukang (1986), pp. 93–4, tables 2 and 3.

[186] Glover and Henderson write of these high-potassia glasses: 'South Indian glass beads were widely traded into South-east Asia in the middle of the 1st millennium BC and reached south China and Korea soon after this, but it is becoming apparent that a distinctive group of potash glasses were being made somewhere between south China and mainland South-east Asia about the same time and some beads made from this material were traded as far north as Korea.' Glover & Henderson (1995), p. 160.

Table 138 *Cobalt-containing glasses excavated from Han dynasty sites in south China, compared with Arikamedu blue glasses from India, plus an analysis of a +16th-century Chinese* fa-hua *glaze*[a]

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	CoO	PbO	CuO	SnO_2	Total
GH-13 Dark-blue bead Western Han, Canton	72.0	3.4	1.65	1.4	1.3	15.3	1.5	1.5	0.05	-.-	0.1	-.-	98.2
GH-14 Dark-blue bead Western Han, Canton	71.7	4.8	1.6	0.7	0.4	16.4	0.35	1.4	0.03	-.-	-.-	-.-	97.4
GH-15 Dark-blue bead Western Han, Kuangsi	74.7	3.0	1.35	0.6	0.3	15.5	0.2	1.7	0.06	-.-	-.-	-.-	97.4
Blue glass bead, excavated from Chhang-sha	-.-	-.-	2.0	1.9	0.4	15.3	2.9	1.3	0.07	0.4	0.04	-.-	24.3
Green glass bead, excavated from Chhang-sha	-.-	-.-	1.4	0.6	0.2	15.1	0.8	1.4	0.04	0.6	0.3	-.-	20.4
Dark-blue drawn glass tube from Arikamedu[b]	77.0	2.1	1.9	2.2	0.4	13.3	0.6	1.7	0.15	0.06	0.04	0.01	99.5
Dark-blue flat fragment of cullet, Arikamedu[c]	73.8	1.8	2.3	1.15	0.3	16.5	0.34	3.0	0.07	0.02	0.03	0.006	99.3
Glaze from a +16th-century Chinese *fa-hua* porcelain *mei-phing*, south China	73.2	3.1	0.7	0.7	-.-	12.3	1.5	5.7	0.6	0.7	2.4	0.4	101.3

[a] Compiled from Zhang Fukang (1986), pp. 93–4, tables 2 and 3; Shi Meiguang *et al.* (1987), p. 18 table 2; Brill (1999), p. 141, and table XIII E, p. 337 (Arikamedu), and Wood *et al.* (1989), p. 174, table 1.
[b] Brill (1999), p. 141, and Table XIII E, p. 337 (Arikamedu).
[c] *Ibid.* These two blue glasses are '1st C AD or later'.

glass. This particular combination of a high-potassia, practically lead-free silicate base, coloured with iron, cobalt, manganese and copper, does not appear in Chinese-made ceramics until the southern *fa-hua* glazes of the +16th century (Table 138 and see pp. 628–31).[187]

High-potassia glasses containing cobalt and dating to the −4th to −1st centuries are usually found in the southern provinces of China. Although apparently imported, some examples may have been reworked within China itself, as they can appear as typical Chinese forms.[188] However, there are other glass-finds from China, dating from the −4th to −1st centuries that contain cobalt oxide as a colourant, and which are far nearer to 'mainstream' Chinese glasses in their compositions, with substantial

[187] Wood *et al.* (1989), p. 29.
[188] Shi Meiguang *et al.* (1987), pp. 19–20.

levels of lead and barium oxides.[189] A few of these glasses can be classified as glazes, as they appear on eye-beads with *faience* bodies where their compositions show typically glass-like proportions (see pp. 474–80 and 614–15).

Chinese Lead-baria Glasses Coloured with Cobalt

The compositions of these cobalt-bearing glasses seem of two types: glasses that are obviously blue, and a second type where the cobalt occurs with substantial levels of iron oxides (1.5 to 5.0% Fe_2O_3) to give a very dark-blue colour that appears nearly black. The latter effect is sometimes used for bead glazes. Major compositional differences are also apparent between the two groups. The blue glasses tend to be nearer to Near Eastern soda-lime types in their essential chemistries, while the higher-iron glasses and glazes are more typically Chinese in their lead-baria make-ups. A list of artefacts analysed in Table 139 are provenanced as follows:

1. –4th- to –1st-century bead glaze, code 94. Eye-bead with a friable terra-cotta body and black glazed surface. ROM 933 × 84.5.[190]
2. (Han dynasty?) Bead black glaze, code 69. Frit-like body with light blue turbid inlay. Beck collection, Cambridge, 'CGS, E, B/2455, sp.gr 3.1'.[191]
3. 2nd century (–175 to –128). Dark-blue glass, code WHG-4, from a Chhu prince's burial in Hsü-chou 徐州, northern Chiangsu province.[192]
4. –4th to –3rd centuries. Dark-blue glass eye-bead, code 54. Dark transparent glass with inlaid white (?) opaque and yellow (?). Moderately weathered.[193]
5. Blue glass from large eye-bead from a Warring States tomb in Honan province.[194]
6. –4th to –3rd centuries. Dark-blue bead, code 50. Eye-bead fragment, dark-blue transparent glass. Possibly from Chin-tshun 金村 near Lo-yang.[195]
7. Babylonian turquoise glass.[196]
8. Egyptian turquoise glass.[197]

Of the above, sample 3 (WHG-4) is the most securely dated, as it comes from the tomb of a Chhu prince 楚國王, who was buried between –175 and –128. The tomb was found in a suburb of Hsü-chou in northern Chiangsu province, and the finds included sixteen glass cups, a fragmentary glass animal (half a pig), and three small

[189] Brill *et al.* (1991), pp. 34–7.
[190] *Ibid.* p. 45 and pp. 50–1, table 1.
[191] *Ibid.* p. 44 and p. 53, table 1.
[192] Shi Meiguang *et al.* (1992), p. 25, table 1.
[193] CMG 671.1 Brill *et al.* (1991), p. 43 and p. 53, table 1.
[194] Zhang Fukang (1986), p. 25 and p. 27, table 1.
[195] CMG 51.6.349B. Brill et al. (1991), p. 43, and p. 53, table 1.
[196] Tsuneo Yoshimizu (1989), p. 87, table 4.
[197] *Ibid.*, p. 87, table 3.

Table 139 *Cobalt-containing glasses and glazes from the −4th to the −1st centuries, found in China*

	Sample	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	CoO	CuO	PbO	SnO_2	BaO	Total
Black bead glaze, −4th to −1st century	1.	41.7	1.9	5.0	2.9	0.5	0.6	2.0	0.04	0.05	0.35	34.5	0.02	10.1	99.7
Black bead glaze, −4th to −1st century	2.	46.9	1.9	4.6	2.7	0.7	0.7	3.0	0.02	0.08	0.5	35.2	0.2	3.1	99.6
Blue glass, −2nd century from Hsü-chou	3.	41.6	1.6	1.5	2.0	0.8	0.15	4.2	0.07	0.08	-.-	25.6	-.-	19.5	97.1
Blue eye-bead glass, −5th to −3rd century	4.	38.8	2.3	0.3	0.6	0.1	0.2	1.75	0.004	0.04	0.05	33.9	-.-	20.0	98.0
Blue glass, −4th to −3rd century	5.	66.2	2.3	1.3	4.5	2.1	7.4	10.6	0.03	0.04	0.4	3.4	0.7	0.7	99.7
Dark-blue glass, −4th to −3rd century	6.	55	2.1	0.6	2.95	1.3	4.0	7.5	0.01	0.02	0.3	15.0	1.0	9.7	99.5
Babylonian soda-lime glass	7.	65.4	1.5	1.5	6.1	5.5	2.5	13.55	-.-	-.-	1.5	-.-	-.-	-.-	97.6
Egyptian soda-lime glass	8.	64.1	1.3	0.5	7.0	3.8	2.8	19.3	-.-	-.-	0.2	-.-	-.-	-.-	99.0

flat pieces of blue glass decorated with eye-bead-like patterns.[198] The authors note of the cobalt-blue fragments:[199]

> We do not know what they were, but perhaps they were intended to be used for decorating other artifacts of some sort. The pieces are about 1.6 centimetres long, 6–12 millimetres wide and 2.5 millimetres thick.

Glasses 5 and 6 (both from eye-beads) are less obviously typical of Chinese lead-baria compositions. In fact glass 5 is much closer in its nature to a Western (in the sense of west from China) soda-lime glass of the –1st millennium (see glasses 7 and 8).[200] This suggests that it may be an imported cobalt-blue glass, mixed with a small amount of Chinese lead-baria metal. Glass 6 may also be a mixture, but in this case one containing more Chinese than imported glass. If these assumptions are correct, then these two blue bead-glasses (5 and 6) provide interesting insights into early Chinese glass-making practice, and also into early sources of cobalt in China.

The black 'glazes' (1 and 2), and the blue glass 4, are much lower in soda and calcia than other blue glasses, but quite high in cobalt. This suggests that, in these cases, the cobalt may *not* have been introduced in the form of a soda-lime glass, but as a concentrated cobalt pigment. Although the origins of the cobalt-colourants used for this latter group are presently unknown, they appear to be of the high-iron type.

Such is the background to cobalt's use within China, prior to the material's adoption as colourant in Chinese low-firing glazes on pottery vessels, which seems to have started in the mid +6th century in the north.[201] High-lead glazes coloured with cobalt later became important productions at northern kilns making coloured glazed earthenwares for the burial trade in the Thang dynasty. Prominent were the *san-tshai* kilns at Kung-hsien and Huang-pao.[202] Lead glazes coloured blue with cobalt oxide joined the typical *san-tshai* colours of copper-green, iron-amber and pale straw, although the cobalt-blues were used more sparingly. However, before discussing Thang dynasty cobalt pigments in detail, the analytical techniques used by investigators in this area should be mentioned briefly, as these have some bearing on the kinds of interpretations that are possible from published data. The analytical methods employed divide broadly into the destructive and the non-destructive.

Destructive Analysis of Cobalt Pigments

Destructive analysis is the preferred method for studying cobalt pigments, as it often allows analysis of the ceramic body, the area of the glaze coloured with the cobalt pigment, and the uncoloured glaze itself if the pigment is of the underglaze- or overglaze-type. Full destructive analysis is the hallmark of the very thorough and

[198] Shi Meiguang *et al.* (1992), p. 23.
[199] *Ibid.*
[200] Glasses of this type were made in the Near East, Central Asia and southern Russia, so it may be risky to assume the imported glass was Near Eastern.
[201] Example cited by Li He (1996), p. 144.
[202] Li Zhiyan & Zhang Fukang (1986), p. 69, table 1; Li Guozhen *et al.* (1986), p. 78, table 2.

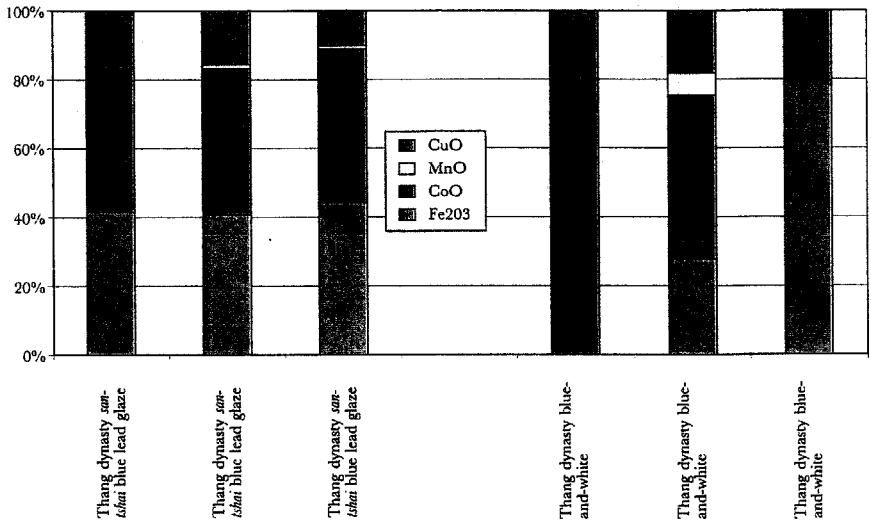


Chart 3 A comparison between Thang dynasty *san-tshai* and Thang underglaze-blue pigments

comprehensive work on cobalt usage that has been carried out in China since the late +1970s, assisted by an abundance of excavated sherd material, often from known kiln sites. Chhen Yao-Chheng [Chen Yaocheng 陳堯成] of the Shanghai Institute of Ceramics has been a leading figure in this work since the late +1970s.[203]

For cobalt pigments it is also useful if nickel, arsenic, copper and sulphur are added to the usual suite of elements examined. The latter elements can help to identify the types of cobalt pigment used, though in practice such full analyses are something of a luxury. Conventionally, data produced from this type of analytical work tends to include separate calculations for real-weight ratios of cobalt oxide-to-iron oxide, cobalt oxide-to-manganese oxide and, sometimes, cobalt oxide to copper oxide, from the pigment areas. These tend to be expressed as Co/Fe, Co/Mn, and Co/Cu ratios, and are often used for discussion, and for comparisons between pigments. Such calculations should also make allowance for the background levels of cobalt, iron, manganese and copper in the plain and uncoloured glazes in order to provide the most realistic estimates of the pigment's compositions. Histograms showing colourant percentages have been used here, in preference to the usual numerical ratios, as these make differences between the pigments rather easier to appreciate.

[203] See particularly Chhen Yao-Chheng *et al.* (1978); Chheng Yao-Chheng *et al.* (1980); Chen Yaocheng *et al.* (1985); Chen Yaocheng (1986); and Chen Yaocheng *et al.* (1995a and b).



Fig. 154 Front view of sherds of Thang dynasty northern white Kung-hsien stonewares decorated with cobalt-blue, excavated at Yang-chou 揚州

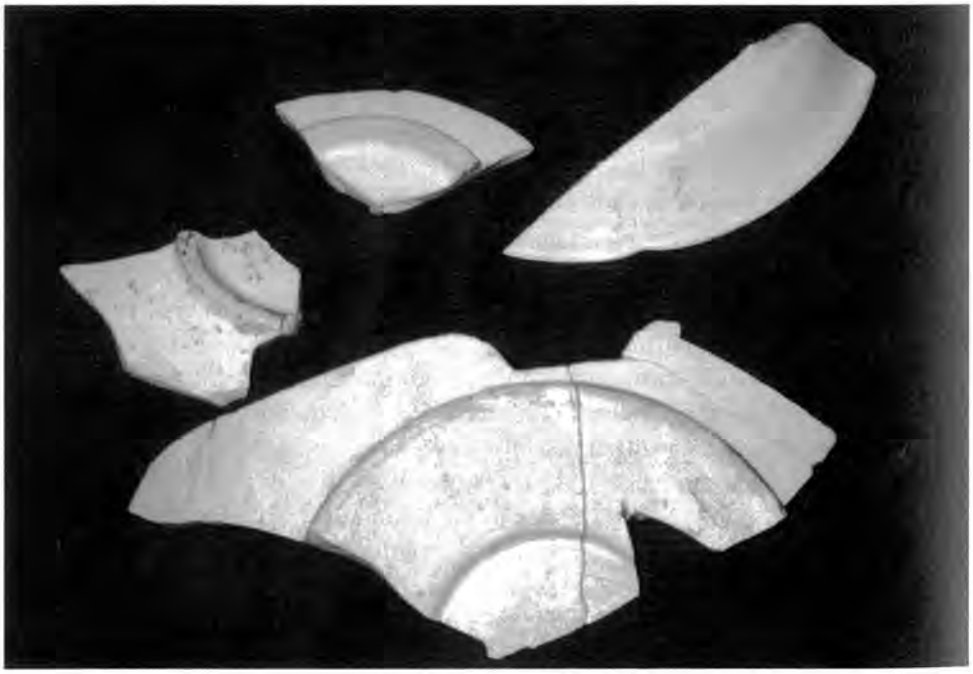


Fig. 155 Back view of sherds of Thang dynasty northern white Kung-hsien stonewares decorated with cobalt-blue, excavated at Yang-chou 揚州

Non-Destructive Analysis

The other major body of research on this subject uses non-destructive airpath energy dispersive X-ray fluorescence analysis, an investigation that began in the West in +1956 (see p. xlviii).[204] Airpath EDXRF works well with heavy elements, so iron, manganese, copper and cobalt show up clearly as peaks in the K-alpha regions of the spectra, produced when focused X-ray beams are reflected from the objects studied. The heights of the peaks in the resulting spectra tend to be used directly to create Co:Mn, and sometimes Co:Fe, ratios for subsequent discussions, usually after allowing for some curvature of the spectral baselines. However, background levels of manganese and iron in the plain glazes tend not to be considered in this type of work, and are only rarely published. Also, iron in the pigment-area is only occasionally analysed, as most studies deal solely with Co/Mn ratios.

It should be mentioned that elemental ratios from the destructive and non-destructive types of analysis are not directly comparable, as one concerns the real weights of the oxides present, and the other the K-alpha peaks of the same elements, when bombarded with X-rays. A broad relationship exits between these two types of results, but not a consistent one.[205] So far, cobalt pigments of the Thang dynasty, Sung, Yuan and early Ming dynasties tend to have been studied destructively, while non-destructive work has dealt mainly with the period +15th century to the present day. In the future, modern non-destructive analytical techniques, such as PIXE (particle-induced X-ray emission), will probably allow full quantitative analysis of glazes, bodies and cobalt pigments to take place, and this combines the advantages of both approaches.

The Nature and Origins of Thang and Liao Dynasty Cobalt Pigments

Full quantitative analyses have been made of Thang dynasty *san-tshai* cobalt pigments, which have proved to be mainly iron-copper-cobalt or copper-cobalt mixtures.[206] They are the purest (that is the highest in cobalt oxide) in China's earlier ceramic history, typically containing some 40–80% CoO. They are also some of the purest cobalt pigments used in the ancient world. The relative purity of these refined ores made it possible to colour high-lead glazes to strong blues, and also to employ similar ores as underglaze-blue pigments, fired in oxidation on white Kung-hsien stonewares.[207]

[204] Stuart Young (1956). A still earlier work on this subject, W. J. Young (1949), also used 'spectroscopic' analysis but no details are given in the paper of the technique used. For later work, using XRF, see Yap & Tang (1984); K. N. Yu & Miao Jianmin (1996); and Miao Chien-Min & Wang Li-Ying (1999).

[205] See Potts (1987), pp. 226–85, for a good introduction to XRF principles.

[206] Li Zhiyan & Zhang Fukang (1986), p. 69, table 1; Li Guozhen *et al.* (1986), p. 78, table 2.

[207] Zhang Zhigang *et al.* (1985), and Chen Yaocheng *et al.* (1995b). Although they are often described as porcelains, even the best examples of Thang dynasty blue-and-white (such as those held at the Yang-chou Pottery Training Centre 揚州陶瓷學院 in Chiangsu province) seem nearer to white stonewares. The authors were able to examine the two sherds analysed in Chen Yaocheng *et al.*'s (1995b) paper, at Yang-chou in +1989. The cobalt pigment was plainly underglaze and white slips covered the slightly yellowish stoneware bodies.

These appear to be the earliest underglaze-cobalt-blue decorated wares in world ceramics. Earlier use of cobalt painting on white ceramics, such as the +9th-century Mesopotamian tin glazed wares found at Samarra, applied cobalt ores or cobalt coloured glazes to the dry tin glazes before firing.[208] The great advantage of underglaze-painting lies in the stability of the pigment. That stability is achieved partly through some combination with the clay body beneath, but also through being less subject to such movement of the glaze at full heat that often affects on-glaze painting. Finer detail is also possible with the underglaze method, as the surfaces are easier to paint and the designs stay where they are applied. The general principle of detailed underglaze painting with a concentrated oxide, however, far pre-dates Chinese wares, as it was used to decorate some Egyptian *faience* wares with manganese pigments during the New Kingdoms period.

There is some compositional overlap between analysed samples of Thang dynasty *san-tshai* blue pigments and the slightly later cobalt ores used for late Thang dynasty underglaze-blue painting (see Chart 3). This suggests that the cobalt may have shared a common source, though where that may have been is still an unresolved problem.

One example of Thang dynasty blue-and-white found at Yang-chou 揚州 is decorated with a Near Eastern pattern, and its presence at Yang-chou suggests that it may have been destined for export to the Islamic world. Yang-chou's strategic position near the junction of the Grand Canal and Yangtze river brought it to prominence during the Thang dynasty, when it received a major part of the inland, waterborne trade from both north and central China. After the An Lu-Shan rebellion 安祿山兵變 of +755, and in contrast to the ransacked north, Yang-chou's economy boomed, aided by displaced businessmen from other cities and foreign traders. The remains of a separate enclave inhabited by Persian residents has been excavated, while the large number of Japanese traders can be estimated from a massacre of over 1,000 of their number at the end of the dynasty. Hundreds of thousands of Thang dynasty ceramic sherds have been excavated at Yang-chou, reflecting both domestic consumption and casualties of export.[209] Near Eastern ceramics with copper-turquoise glazes have been found in the city, perhaps used there by the Persian community.[210] This suggests that a two-way trade in ceramics with the Near East was operating at the time when Thang dynasty blue-and-white was made, though heavily weighted towards the export of Chinese wares. Cobalt ores imported from West Asia therefore seem one possible source for the Thang dynasty pigments.

Analysis, though, shows that Thang dynasty cobalt ores bear little relation to contemporary cobalt-blue pigments used on Mesopotamian ceramics, such as those excavated from Samarra in Iraq, and probably made at Old Basra.[211] There are

[208] Tamari (1995), pp. 139–40. Where cobalt glazes are used (rather than cobalt pigments), the blue painting appears in slight relief.
[209] Cf. Wang Chhin-Chin & Li Chiu-Hai (1991), p. 91.
[210] Zhang Fukang *et al.* (1985), p. 111 (abstract).
[211] Mason & Tite (1997), p. 49.

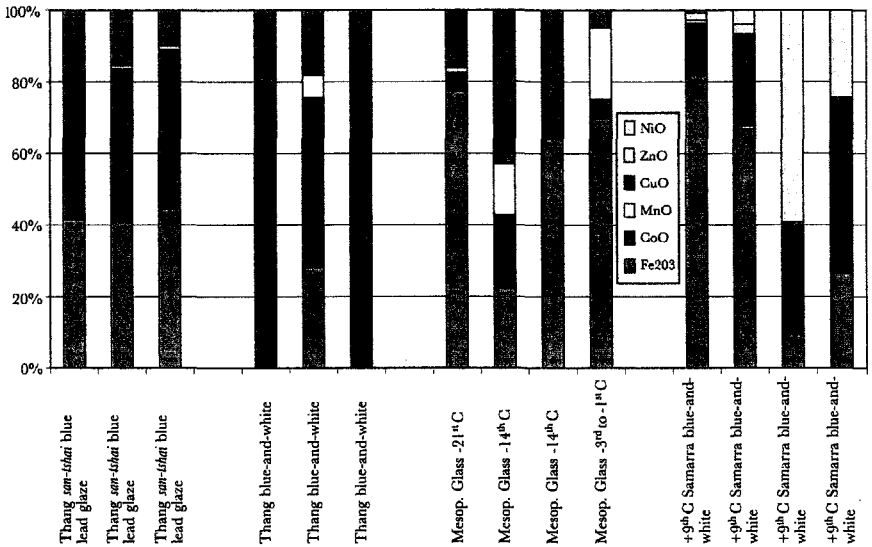


Chart 4 Thang dynasty *san-tshai* and hang dynasty underglaze-blue cobalt pigments compared with cobalt colourants used in Mesopotamian glasses and Mesopotamian blue-and-white ceramics

differences too between Thang dynasty cobalt pigments and those used in earlier Mesopotamian blue glass (see Chart 4). Thang dynasty pigments often contain substantial amounts of copper (c. 10–20% CuO) and no nickel, while copper levels in Mesopotamian blue glaze pigments rarely exceed 2% and nickel oxide levels can be as high as 40%.[212] Pigment balances in Mesopotamian blue *glasses* are nearer to Thang dynasty blue colourants, although still a long way from a true match, besides being of very much earlier manufacture.

The levels of calcia and soda in Thang dynasty blue lead glazes were also extremely low. This last detail shows that the cobalt material used in lead glazes could not have been introduced in the form of an imported blue soda-lime glass (another possible 'Western' source), so must have been purchased in the form of a cobalt-rich ore.

A detailed study of one example of a Thang dynasty underglaze-blue pigment was made in China and reported in +1995.[213] Chhen Yao-Chheng [Chen Yaocheng] and his co-workers found sulphur present in the pigment at a concentration of about 0.14%. They suggest that the original ore was probably a cobalt sulphide. After listing eleven sulphur-containing cobalt minerals they limit the options to linnaeite (Co_3S_4) and cattierite (CoS_2) and note that foreign sources of linnaeite and

[212] Kleinmann (1991), p. 333, table 1.
[213] Chen Yaocheng *et al.* (1995b), p. 208.

cattierite occur in Zaire and Zimbabwe in Africa, and at Saiyan-Tuwa in Central Asia. Recent exploration has also identified cobalt sulphide deposits in China, near the city of Chin-chhang 金昌 in Kansu province, and also at a site 'somewhere in Hebei [Hopei]'.[214] It should be noted that these represent relatively modern identifications of cobalt-rich ore-bodies, and are not necessarily claimed as ancient sources for the element. Chhen Yao-Chheng and his colleagues discount the use of Persian cobalt in Thang dynasty wares because of earlier research undertaken by one of the group. That was Chang Fu-Khang [Zhang Fukang], who found arsenic in all Persian blue pigments (+13th to +18th centuries) that he examined. No arsenic appeared in the Thang dynasty Chinese pigment reported on in +1995. As linnaeite minerals have been identified as part of the complex cobalt-bearing geology at the Qamsar mine near Kashan,[215] the importation of cobalt ore from West Asia in the Thang period might still seem a possibility. However, the very obvious differences that exist between Near Eastern cobalt pigments of the +8th to +9th centuries, mentioned above, and the absence of arsenic in Thang dynasty example studied, remain as obstacles to this view.

There is some sparse evidence for the use of cobalt oxide in Chinese glazes during the Liao dynasty. For example, in north China a very impure nickel-cobalt ore has been reported for a Liao dynasty *san-tshai* lead glaze. This discovery is remarkable because of the extreme rarity of blue lead glazes during the Liao dynasty.[216] It suggests that the traditional types of cobalt ore used in north China in the Thang dynasty ceramics may have not have been available to Liao dynasty potters.[217]

SOUTHERN CHINA: CHEKIANG AND YUNNAN PROVINCES, AND CHING-TE-CHEN 景德鎮

In south China, by contrast, the +10th century saw the beginnings of the great southern underglaze-blue tradition. The earliest finds so far come from southern Chekiang province, where underglaze-blue painting is found on an early example of white porcelain.[218] The blue painting appears on some fragments of a bowl found in the foundations of the Chin-sha Pagoda 金沙塔 in Lung-chhüan county 龍泉縣, together with some objects dated to +977.[219] The cobalt pigment used contained only manganese oxide and cobalt oxide at about 1.06% and 0.1% respectively. This weak cobalt pigment supplied a dull blue colour to the painting, which suggested to the investigators that selection and preparation of cobalt ores at this time were still undeveloped.[220] Chhen Yao-Chheng and his team believe that the body-material

[214] *Ibid.*, pp. 208–9.
[215] Kleinmann (1991), p. 334.
[216] Anon. (1988b), Borax Consolidated Limited, p. 127, table 7–5.
[217] Chen Yaocheng *et al.* (1995b), p. 208.
[218] Although the body of the Northern Sung blue-and-white bowl contained 1.62% Fe_2O_3, at the top range for porcelain, its TiO_2 content was only 0.01%. This shows that the bowl was made from true porcelain stone, albeit a low-grade one. See body analysis in Table 2 in Chhen Yao-Chheng *et al.* (1980), p. 548.
[219] Chhen Yao-Chheng *et al.* (1980), p. 544.
[220] *Ibid.*, p. 547.

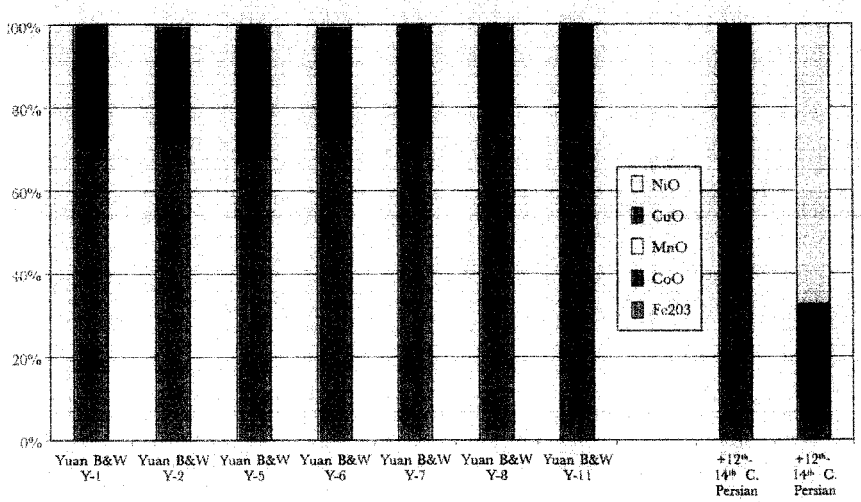


Chart 5 Chinese Yuan dynasty Ching-te-chen underglaze-blue cobalt pigments and Persian underglaze-blue cobalt pigments (+12th to +14th centuries) compared

for the bowl places its production somewhere in the Lung-chhüan area, and that the cobalt pigment was a local cobalt ore from Chekiang province. That ore was similar to, but less pure than, the asbolites from Chekiang province that were used later by the porcelain industry at Ching-te-chen. Thus it appears that small-scale provincial production of blue-and-white porcelain once existed in southern Chekiang province, at a time before the great Lung-chhüan celadon industry was developed.

A further report of early blue-and-white production in south China concerns the Chi-chou kiln-complex 吉州窯區 in Chiangsi province, where a small blue-and-white saucer was found in a mid-period context (that is +10th to +11th centuries) in +1975. No analyses are offered in this case, so the nature of this cobalt pigment remains unknown.[221]

This pattern of using local asbolite ores on rather poor-quality bodies may also be traced to the Yü-hsi kilns 玉溪窯 in Yunnan province, in China's south-western region, where underglaze-blue wares were made from the late +14th century.[222] Ash-rich lime glazes tended to be used at Yü-hsi, and these often caused the cobalt pigments to diffuse within the glazes, blurring the painted designs.

The sporadic productions of blue-and-white porcelain, mentioned above, seem to have established no large-scale industries in southern China, and these did not really emerge until underglaze-cobalt-blue painting was adopted at Ching-te-chen

[221] Cf. Thang Chhang-Pu (1980), p. 4.
[222] Chen Yaocheng *et al.* (1986), p. 128; Chen Yaocheng *et al.* (1989b), p. 200.

in the early +14th century. The development of blue-and-white porcelain at Ching-te-chen was an event of major significance, and resulted in one of the most widely exported and influential wares in ceramic history. It occurred at a kiln-complex where a huge and efficient production of *chhing-pai* 青白 wares had already been established. High levels of craft skills and workshop organisation were therefore in place when underglaze painting with cobalt ores was introduced, and even some of the earliest examples seem highly accomplished.[223] Glazes midway between the transparent lime glazes of the *chhing-pai* type, and the slightly opaque low-lime 'egg white' or *luan-pai* 卵白 glazes, developed earlier in the Yuan dynasty. They became standard compositions for the new underglaze-blue wares, probably containing between 8 and 14% 'glaze ash' (calcium carbonate) in the glaze recipes.[224]

Cobalt-Bearing Pigments Used at Ching-te-chen in the Yuan Dynasty

All the Yuan dynasty Ching-te-chen underglaze-blue pigments so far examined are of the same constitution, i.e. high-iron cobalts with minimal manganese contents (see Chart 5). Where arsenic has been sought in analysis it has sometimes been found.[225] When the ambient iron levels in the uncoloured porcelain glazes are subtracted from the iron levels in the pigment areas, most examples correspond to iron oxide: cobalt oxide ratios of about 4:1 (by weight %).[226] This makes underglaze-blue pigments used at Ching-te-chen during the Yuan dynasty quite different from those used at sites such as Lung-chhüan in Chekiang province and Yü-hsi in Yunnan province, for the latter employed local manganese-rich ores.[227] It seems also that the major blue-and-white kilns at Ching-te-chen, namely Hu-thien 湖田 and Lo-ma-chhiao 落馬橋, both used iron-rich pigments during the Yuan dynasty. Hu-thien often made wares for the court, while Lo-ma-chhiao concentrated on popular blue-and-white.

The traditional view is that Yuan dynasty blue-and-white porcelain from Ching-te-chen was decorated with cobalt-ores from mines at Qamsar, near Kashan in Persia, the operation of which are described in Abu'l Qasim's text. Two analyses exist of Persian underglaze-blue wares from Kashan, so it is possible to compare cobalt pigments used in Persia with those used at Ching-to-chen during the Yuan dynasty[228]

[223] As Liu Xinyuan (1992), p. 47, notes: 'sites of Song [Sung] kilns in Jingdezhen [Ching-te-chen] producing *qingbai* [*chhing-pai*] wares are scattered in some 30 villages on about 136 mounds which stretch for nearly 100 *li*.' Liu cites Feng Hsien-Ming's expertise in estimating that of *chhing-pai* wares found all over China (about two-thirds of the landmass), the majority came from Ching-te-chen. Although a few provinces produced their own *chhing-pai* wares, no other Sung dynasty kiln came even close to Ching-te-chen in market share.

[224] Chhen Yao-Chheng *et al.* (1985), p. 318, tables 15-14.

[225] Wood (1999), p. 62.

[226] The validity of this approach is confirmed by the finding of a similar Co:Fe ratio when unreacted iron-cobalt pigments particles were analysed by microprobe methods on an underfired example of Yuan dynasty Ching-te-chen blue-and-white. See the study of sample Y-11 in Chen Yaocheng *et al.* (1986), pp. 126–7.

[227] Chen Yaocheng *et al.* (1986), pp. 122–8. The authors believe that the Yuan dynasty Yü-hsi blue-and-white sample that they examined was decorated with local asbolite from Yunnan province, a cobalt ore that was high in manganese and that also contained minor amounts of iron oxides.

[228] Chart developed from Chhen Yao-Chheng *et al.* (1985), p. 305, table 15.5, and Kleinmann (1990), p. 333, table 1.

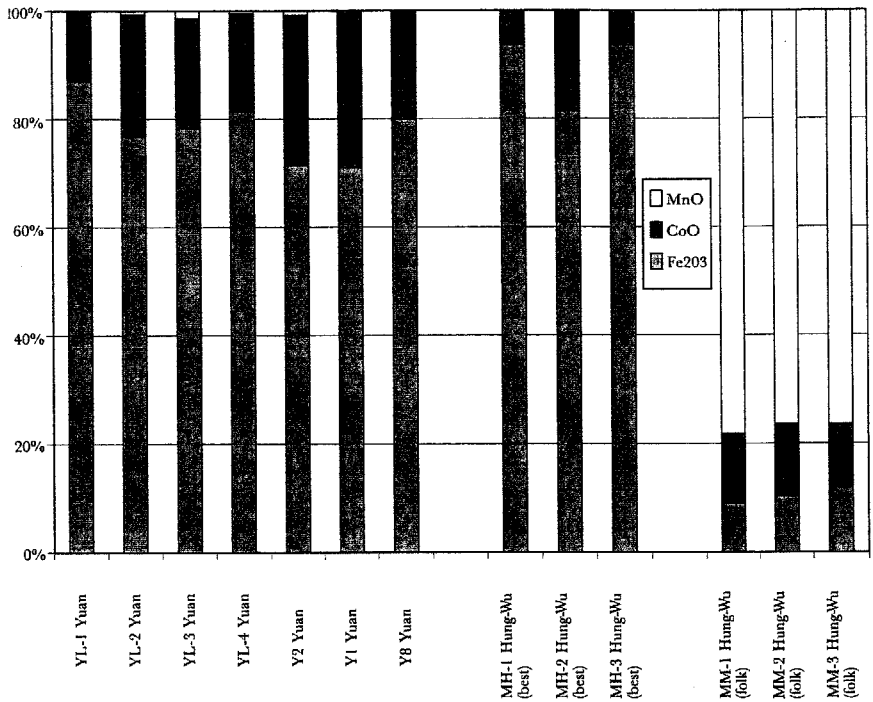


Chart 6 Yuan and Hung-Wu period cobalt pigments used at Ching-te-chen compared

Chart 5 shows that Persian potters used two very different styles of cobalt pigment for their underglaze-blue wares, at a time corresponding to the Yuan dynasty. The first was a high-iron cobalt material, much like that used for Ching-te-chen wares, and the second a high-nickel ore with only about 10% of iron oxides. All examples (Chinese and Persian alike) contained comparable amounts of cobalt oxide, that is some 20–25% of the pigments' active colourants.

No examples of high-nickel cobalts have yet been found on Yuan dynasty Ching-te-chen wares. This suggests that, had their pigments been imported from Persia, high-iron rather than high-nickel types would have been specified by the Ching-te-chen potters. If this were the case it would also have meant that miners or merchants at Qamsar could have distinguished between the two types of ore. Although samples of unweathered ores would have been hard to tell apart by sight, the hydrated 'skins' that are often present on the ores-bodies might have indicated whether the underlying ores were rich in nickel or in iron. Perhaps firing-tests were used to support these assumptions.[229]

[229] Pers. comm. Chris Doherty, Oxford.

Yuan dynasty underglaze blue pigments at Ching-te-chen therefore display better matches with cobalt pigments used in Persia than the Thang dynasty cobalt pigments discussed above. Liu Xinyuan [Liu Hsin-Yüan] certainly holds that Qamsar was the source for cobalt during the Yuan dynasty, and suggests that the term *sulaimani*, a name for cobalt used at Qamsar, may have been the origin for the Chinese word *Su-ni-ma* 蘇泥麻.[230] Because of the imperial nature of some of Ching-te-chen's earliest blue-and-white porcelain, Liu suggests that official channels may have been used to import the material to Ching-te-chen:[231]

> From Yuan imperial wares excavated at Zhushan [Chu-shan] 珠山, this writer is of the opinion that Islamic pigments, decorative styles and Islamic techniques probably found their way to the Fuliang [Fu-liang] Porcelain Office 浮梁瓷局 through the Directorate General for Precious Metals and Jewel Artisans in Various Circuits under the Bureau for Imperial Manufacture.[232]

The fact that in the Yuan dynasty north and south China were unified, and trade across the greater Mongol empire was encouraged,[233] meant that international communication could be efficient. These factors would also tend to extend the possibilities for possible trade in cobalt during the Yuan period. It is particularly significant that Abu'l Qasim, writing in +1301, identifies *two* sources for cobalt used with Persian ceramics in his time: Qamsar and 'another type that comes from Farangistan and is ash coloured and soft.'[234] Farangistan is the Persian name for Europe.

For sources of arsenical cobalt in China James Watt notes that by consulting a +1950s source-work on mineralogy:[235]

> one finds several arsenic cobalt ores mentioned as occurring in China: erythrite in Chin-hua 金華 and Chu-chi 諸暨 in Chekiang province; danaite ($FeAsS$ or FeS_2FeAs_2), in which part of the iron has been displaced by cobalt, in Hunan province and Yünnan province; and smaltite or smaltine, $CoAs_2$, which is mentioned as an important cobalt ore and that it occurs in lateritic deposits in many areas of Yünnan.

Moving beyond China again, another occurrence of arsenic-rich iron-cobalt sulphide is worked at the Khetri mines in Rajputana in India, and is mentioned in

[230] Liu Hsin-Yüan (1989), p. 74. Watt (1979), p. 67, also sees *sulaimani* as being a source for a Chinese name for an imported cobalt ore, namely, *su-ma-li* 蘇麻離: 'On the Chinese side there is a persistent tradition that in the beginning of the fifteenth century (Yung-lo and Hsüan-te) the potters used a cobalt ore called su-ma-li blue. There is little doubt that the term su-ma-li, which has puzzled commentators for the past fifty years, is one of the various Chinese transliterations of Sulaimani.'

[231] Liu Xinyuan (1992), p. 49.

[232] We have described the Porcelain Bureau, see p. 186. It was a sub-bureau of the *Chu-lu Chin-yü Jen-chiang Tsung-kuan Fu* 諸路金玉人匠總管府 (Directorate General for Precious Metals and Jewel Artisans in Various Circuits), which in turn reported to the Imperial Manufactories Commission.

[233] Trade in Yuan dynasty China was controlled by *Ortoy* (merchant trade associations, *wo-erh-to* 斡耳朵 in Chinese), composed primarily of Muslims and Uighurs, see Endicott-West (1989), pp. 137–54. Between +1284 and +1322 private trade was restricted, to be followed by a flourishing period +1323–68, see Shih Ching-fei (2001), pp. 170–2.

[234] Allan (1973), p. 112.

[235] Watt (1979), p. 65.

Table 140 *Compositions of Chinese asbolites*[a]

	SiO_2	Al_2O_3	TiO_2	CuO	BaO	NiO	MgO	CaO	K_2O	Na_2O	Fe_2O_3	MnO	CoO	As_2O_3	loss	Total
Yunnan asbolite	28.8	36.4	0.12	0.7	-.-	-.-	0.8	0.65	0.09	0.45	3.2	20.6	2.8	-.-	4.5	99.1
Yunnan asbolite	28.7	35.5	0.35	0.8	-.-	-.-	0.4	0.4	0.05	0.3	2.8	22.85	6.1	-.-	2.02	100.3
Yunnan asbolite	29.4	33.3	0.4	0.6	trace	0.05	trace	0.7	0.4	0.2	6.7	19.6	4.5	-.-	4.4	100.3
Yunnan asbolite	24.8	29.3	-.-	-.-	-.-	0.1	0.3	0.04	-.-	-.-	7.2	26.8	5.4	0.09	-.-	94.0
Yunnan asbolite	0.9	26.5	-.-	-.-	-.-	0.15	0.02	0.06	-.-	-.-	1.2	49.5	11.2	0.04	-.-	89.6
Chekiang asbolite	21.15	22.0	1.8	0.1	2.1	0.4	0.2	0.2	-.-	-.-	8.0	34.8	2.1	-.-	6.65	99.5
Chekiang asbolite	42.5	23.7	-.-	-.-	-.-	0.2	0.3	0.07	-.-	0.02	3.3	24.0	2.2	0.06	-.-	98.4
Chekiang asbolite	6.0	27.2	-.-	-.-	-.-	1.2	0.09	0.03	-.-	<0.05	1.5	48.9	6.9	0.05	-.-	91.9
Chekiang asbolite	22.5	19.1	-.-	-.-	-.-	0.4	-.-	-.-	-.-	-.-	16.9	35.0	6.1	-.-	-.-	100.0
Chiangsi asbolite	42.5	20.95	-.-	0.2	1.2	0.2	0.5	0.4	1.2	0.1	5.2	22.5	1.4	-.-	4.2	100.6
Chiangsi asbolite	25.6	21.3	-.-	-.-	-.-	0.4	0.2	0.06	-.-	0.01	6.51	36.1	5.0	0.05	-.-	95.2

[a] Chhen Yao-Chheng *et al.* (1985), p. 321, table 15-15

W. J. Young's +1949 paper on Ching-te-chen underglaze pigments.[236] In short, the usual source proposed for Yuan dynasty Ching-te-chen cobalt pigments, i.e. Qamsar in Persia, has merits on both compositional and historical grounds. Nevertheless, Persia is far from being the only country where this kind of rock is found.

UNDERGLAZE-BLUE IN THE MING DYNASTY: HUNG-WU REIGN PERIOD

Whatever its origins, the high-iron cobalt used at Ching-te-chen in the Yuan dynasty seems to have run short in the first reign of the Ming dynasty, that of the Hung-Wu emperor. Most Persian and Arab traders left China at the end of the Yuan dynasty, and the new Hung-Wu emperor prohibited sea-trading activity (see pp. 717–18).[237] This may explain why the Hung-Wu reign period is better know for its underglaze-copper-red wares, than for its small number of underglaze-cobalt-blue wares. During the reign period an obvious difference between high- and lower-quality Ching-te-chen blue-and-white wares began to appear in the potters' choice of pigment (see Chart 7). The best porcelains used high-iron ores slightly poorer in cobalt than those the Yuan dynasty, while *min-yao* 民窯 wares from the popular kilns used high-manganese cobalts with low iron contents.[238]

In fact, the types of high-manganese cobalt ores used for the lower grades of Hung-wu blue-and-white can be traced throughout 300 years of blue-and-white production at Ching-te-chen during the Ming dynasty. This fact was established in an unpublished paper at the second International Conference on Ancient Chinese Pottery and Porcelain in Peking in +1985.[239] These data have been combined with analyses of native asbolites from the three provinces known to have supplied cobalt-ores to Ching-te-chen, during the Ming and Chhing dynasties: Yunnan, Chekiang and Chiangsi (Table 140).[240]

The close parallels between colourant percentages in Ching-te-chen folk blue-and-white underglaze-blue pigments and native Chinese asbolites show clearly when thirteen examples of Ming dynasty underglaze have their blue colourants averaged, and then compared with the average colourants of the eleven asbolite examples above (see Chart 7).

Chang Chih-Kang [Zhang Zhigang 張志剛] and his co-workers suggest that until the Hung-Chih reign period popular kilns used asbolite ores from Chekiang and Chiangsi provinces. After the Hung-Chih reign period, asbolites from Chekiang

[236] See Young (1949), p. 23, quoting Mallet (1881).

[237] Bailey (1996), p. 8.

[238] Developed from Chang Chih-Kang *et al.* (1999), p. 242, table 1. An interesting use has been uncovered of a high-iron cobalt paint-pigment on a late +14th-century Chinese base-metal figurine, suggesting that cobalt also saw some use in the cold decoration of metalwork: described by Cowell *et al.* in a conference paper 'A Study of Later Chinese Metalwork' (in press).

[239] Zhang Zhigang *et al.* (1985) (poster-paper). Data from this paper also appear in a chapter on Chinese blue-and-white, published in Shanghai in +1985. Chhen Yao-Chheng *et al.* (1985), pp. 307–8, table 15-7. They have been adapted here, using the 'background iron' subtraction approach, used for the other histograms in this section.

[240] *Ibid.*, p. 321, table 15-15.

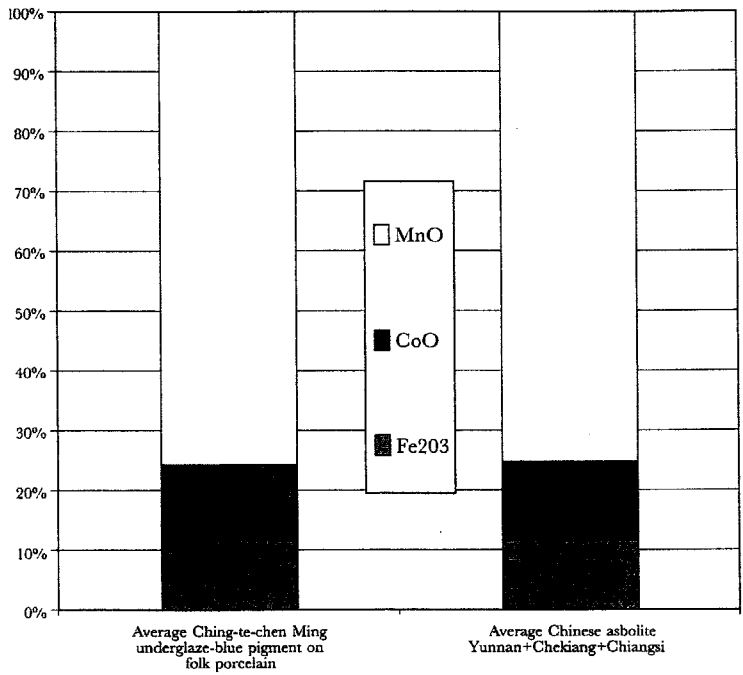


Chart 7 Ratios of oxide colourants in underglaze-blue pigments in Ching-te-chen popular porcelains, Hung-Wu period to Chhung-Chen period (n = 13). Compared with oxide colourant proportions in typical Chinese asbolites (n = 11)

and Yunnan provinces were preferred: 'It was after that time that very nice popular blue-and-white porcelain could be made with these cobalt ores as pigment.'[241]

FA-HUA GLAZES

Similar associations with the compositions of native Chinese asbolites are seen in cobalt colourants used in lower-firing, oxidised Chinese *fa-hua* 琺華 glazes, made from the early Ming until the early Chhing dynasty (see pp. 512–14). These too used high-manganese cobalt ores, but for three rather different effects. Sometimes the ores colour the alkaline glazes an inky-black; sometimes at lower concentrations they give aubergine colours, thus exploiting the high manganese contents in the ores; and sometimes they produce purple-blues. These last colours were achieved

[241] Zhang Zhigang *et al.* (1985), p. 40.

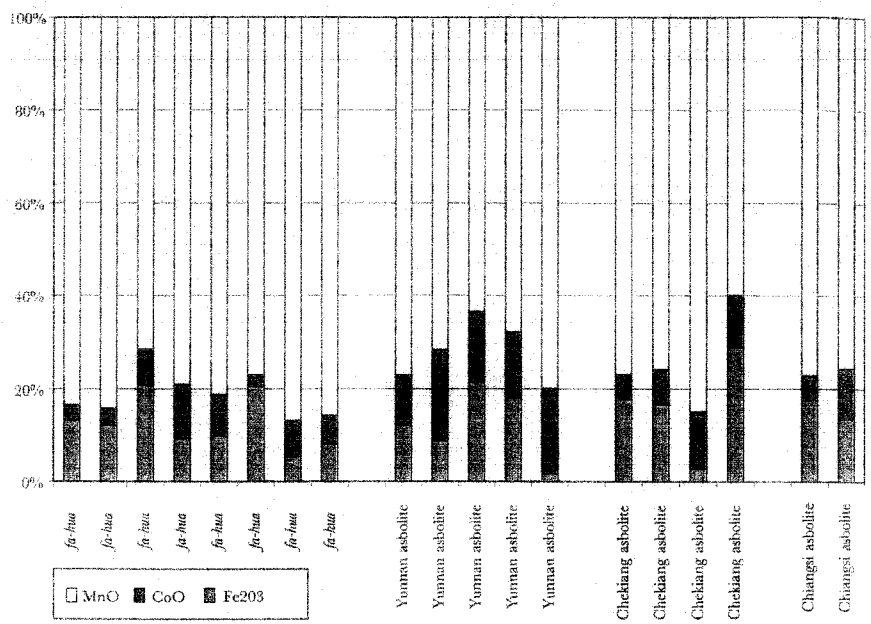


Chart 8 Iron, cobalt and manganese oxide ratios in Chinese *fa-hua* glaze colourants compared with typical south Chinese asbolites

by mixing copper-tin pigments with manganese-cobalt ores, thereby adding a copper-turquoise component to the cobalt's inky-black tone.[242]

Analysis suggests that poor grades of asbolites (i.e. ores higher in manganese and lower in cobalt) were used in *fa-hua* glazes in both north and south China throughout the Ming dynasty. At present, the sources for these pigments are unknown, although they are likely to have been various as *fa-hua* and other alkaline-glazed wares were made in both northern and southern kilns for many hundreds of years.

+15TH-CENTURY UNDERGLAZE-BLUE PIGMENTS

Yung-Le and Hsüan-Te period blue-and-white wares, made at the Ching-te-chen popular kilns, followed the practice of using high-manganese Chinese asbolite ores as their main pigments.[243] Nonetheless, premier blue-and-white wares made during the early +15th century continued to use high-iron cobalts. Now, however, the cobalt contained small but significant contents of manganese, a feature that distinguishes

[242] Wood *et al.* (1989), p. 179.
[243] Zhang Zhigang *et al.* (1985), p. 40; Li He (1996), p. 211.

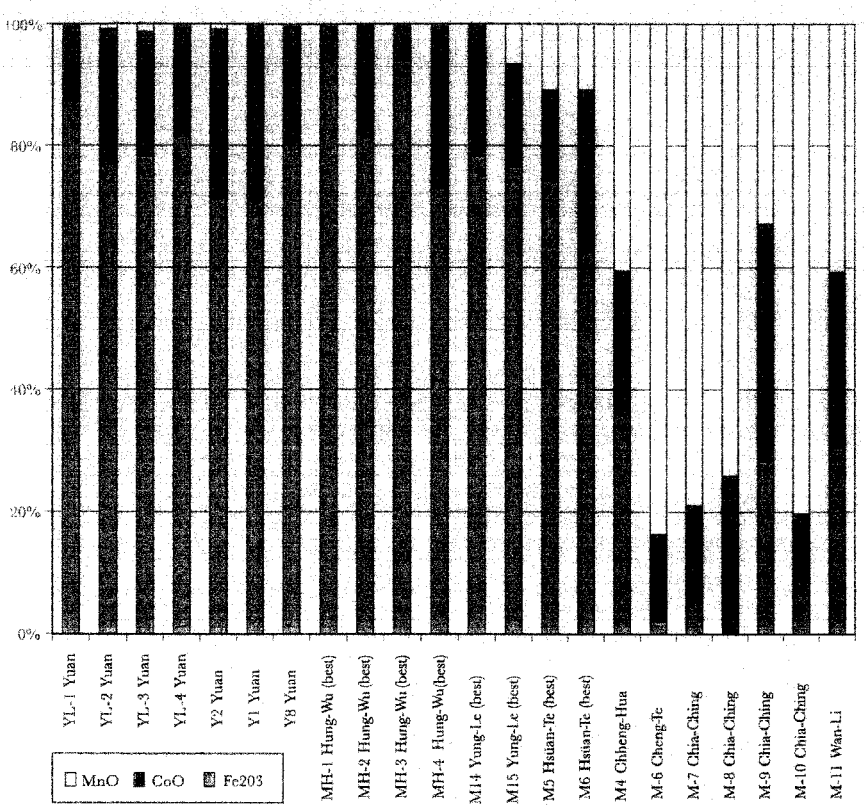


Chart 9 Relative weights of colouring oxides in better-quality Ching-te-chen underglaze-blue pigments: $+14^{th}$ to $+16^{th}$ centuries

early $+15^{th}$-century blue-and-white porcelains from their $+14^{th}$-century equivalents.[244] There is a tradition that during the Yung-Le and Hsüan-Te reign periods, potters used imported cobalt ores mixed with small amounts of the native types in order to improve the character of their underglaze-blue painting. Analysis seems to support this view, with data suggesting mixtures of about 9:1 of the high-iron and high-manganese materials for the best underglaze-blue painting.

The types of high-iron cobalt used during the Yung-Le and Hsüan-Te reign periods tended to diffuse through the glazes at the height of the firing to develop dark crystallites of magnetite (Fe_3O_4) on the glaze surfaces. This produced the celebrated

[244] Zhang Zhigang *et al.* (1985), p. 40; Zhang Zhigang *et al.* (1989), pp. 280–3.

'heaped and piled' quality, so much admired by later connoisseurs.[245] This was not an effect associated with high-manganese cobalt ores, though it was sometimes laboriously copied in the Chhing dynasty using manganese-cobalt ores applied in a myriad of tiny dark-blue dots to cobalt painting before glazing.[246]

A more complicated image of cobalt usage emerges in Ching-te-chen fine wares of the later +15th century, with one commentator noting that:[247]

> cobalt that had been imported during the Yongle-Xuande [Yung-Le Hsüan-Te] period continued to be used in the following reigns when the ports were closed to further imports . . . During the reign of Chenghua [Chheng-Hua] (1465–87), imported cobalt was still used to decorate most imperial wares, but not the best pieces, or *doucai* [*tou-tshai* 斗彩] wares, possibly because the soft elegant effect resulting from the use of Chinese cobalt was created deliberately to meet the emperor's taste.

A return to sources of cobalt richer in iron (and also high in cobalt oxide itself) can be traced in some fine Chia-Ching period blue-and-white wares, and some premier Wan-Li period porcelains (see Chart 9).

This material owes its deep violet-blue colour mainly to its high cobalt content, and is the so-called *hui* (Mohammedan, 回) blue, with its origins suggested variously in Yunnan province, Khwarism in Central Asia,[248] or 'ancient Arabia'. As Watt notes, however, these various interpretations are not necessarily mutually exclusive:[249]

> There is the possibility that Hui-ch'ing [hui-chhing 回青] . . . was not only a trade name given to . . . imported cobalt ore, but was later applied to the cobalt ore found in Yunnan which possessed exactly the same, or very similar properties.

NAMES AND DESCRIPTIONS OF CHINESE COBALT

Despite the very obvious compositional differences between high-iron and high-manganese cobalt ores, the colours they provided in reduction were not too different. Ferrous (iron (II)) oxide supplied a grey component to the cobalt-blue colour and manganese a grey-brown. It is possible too that high-alumina asbolites cooled the manganese colours somewhat through the generation of small amounts of the cobalt aluminate mineral.

While the compositions of Chinese asbolites seem much the same from province to province, a variety of names are used for the ores in the traditional texts. For

[245] Chen Yaocheng *et al.* (1990), pp. 113–31; Ho & Bronson (1990), pp. 119–21.

[246] See Wood (1999), p. 66, for examples. Nowadays at Ching-te-chen small amounts of chrome oxide are added to the cobalt pigments to fake and to imitate this 'heaped and piled' effect.

[247] Li He (1996), p. 211.

[248] *Ibid.*

[249] Watt (1979), pp. 72–3. It is interesting that Andrews (1962), pp. 167–8, describes the discovery of cobalt ores in Burma (about 700 kilometres north of Rangoon) in the +1920s when erythrite blooms were observed on exposed lead-zinc ores. Similar lead-silver-zinc ores were worked in the area by Chinese miners from Yunnan province in the +15th century, and dumps of lead slag still remain from this activity at the site. This raises the possibility that some cobalt-rich materials may have been imported from Burma via Yunnan.

example, *Thien Kung Khai Wu* (The Exploitation of the Works of Nature, +1637) talks of an ore called *wu-ming-i* 無名異:[250]

Wu-ming-i was used as a blue pigment for painting porcelains. The mineral is found near the earth's surface not more than three feet (*chhih* 尺) down at the deepest and occurs in many provinces. It exists in top, medium or low-grade varieties. Before use it was roasted in a red-hot stove [i.e. calcined], whereupon the top-grade material turned peacock blue, the medium light blue and the low grade a shade like brown earth. Each catty of untreated ore produced only seven ounces of top-grade *wu-ming-i*, while the proportions of medium and low grade were correspondingly smaller. The top-grade material was used for painting high-quality fine porcelains and dragon and phoenix designs on imperial wares . . . the blue colouring material used at Jao-chou used 'Chekiang material' from mountains in that province as its best grade . . . After roasting the material was ground into a very fine powder with pestle and mortar and was then mixed with water for painting. It was black while being ground and suspended in water but after firing comes out blue.

Two samples of *wu-ming-i* have been analysed recently, when they proved to be manganese hydroxide nodules with associated iron, i.e. similar to typical asbolite cobalt ores in their natures. However, they contained only 0.1% and 0.18% cobalt oxide respectively. This is too little to make high-quality underglaze-blue pigments, although somewhat reminiscent of cobalt ores used on Lung-chhüan blue-and-white during the Northern Sung dynasty. The authors suggest that these were medicinal *wu-ming-i*, rather than ceramic pigment versions of the material.[251]

In the +16th century *su-lai-man* 速來蠻 and *su-ma-li* 蘇麻離 were referred to, while *hui-chhing* 回青 was imported by land and by sea. Another material known as 'foreign *hui-chhing*' from Yunnan could have been a local ore, i.e. asbolite. From the end of the +16th century onwards, no more mention was made of imported cobalt until the +20th century. Among native cobalts, from the +17th century on *hui-chhing* from Yunnan became increasingly important, while cheaper varieties of cobalt from Chiangsi and Kuangtung provinces could be admixed with better grades. It probably became the chief source after the late +18th century.[252]

The best blue, however, was said to be that from Shao-hsing 紹興 and Chin-hua 金華 in Chekiang province, which could have been erythrite.[253] Indigenous cobalt called '*pho-thang-chhing* 陂塘青' was mined in Le-phing county 樂平縣 near Ching-te-chen. By the Chia-Ching reign period this ore was depleted, and another cobalt called *shih-tzu-chhing* (*shih-chhing* for short) 石子青 (石青) was substituted. The latter

[250] *Thien Kung Khai Wu*, ch. 7, pp. 7b, 8b; Sun & Sun (1966), pp. 154–5.

[251] Chen Yaocheng *et al.* (1995a), p. 293. James Watt, however, suggests that there may be a confusion in *Thien Kung Khai Wu* between *wu-ming-i* – which has shown on analysis to be, variously, iron ore, pyrolusite or a manganese-iron ore – and *wu-ming-tzu* 無名字 – 'which has always been one of the names of wad, a manganese ore often with cobalt (and iron and copper) impurities, which becomes shih-ch'ing [chhing] 石青 when the cobalt content is high enough, or perhaps even Hui-ch'ing 回青 when it becomes earthy cobalt or asbolite $CoMn_2O_5 \cdot 4H_2O$.' Watt (1979), p. 78.

[252] Chou Jen *et al.* (1958), pp. 72–4.

[253] Medley (1993), p. 70. For a discussion of the various etymons for cobalt-blue in Chinese, and textual discussion, see Watt (1979).

was produced in Jui-chou prefecture, north-west of Pho-yang lake 鄱陽湖 in Chiangsi province.[254]

Thao Shuo (+1774) summed up the consensus, and described the retrieval of cobalt ore:[255]

> Both deep-blue monochromes and blue-and-white use cobalt from Chekiang that is found on hills in the two counties of Shao-hsing and Chin-hua. Collectors go out and gather it and wash away earth that sticks to it in stream water. It is dark yellow in colour, and large round pieces are best. Brought back to the kilns and stored under the floor of furnaces for three days, it is then taken out, carefully washed and sold. Cobalt from hills in Chiangsi and Kuangtung is thin in colour and doesn't fire well, so it is only used for low-quality popular wares.

When brought into the factory still mixed with its surrounding soil, cobalt was prepared for use by being picked over carefully. It was said that the finest ore was found associated with white clay, second-quality with red soil, and lowest-quality with sand. After washing, the material was roasted in a small kiln for 24 hours, then ground and sieved to separate ore from soil.[256] All cobalts had value while imported minerals and best-quality ores were highly precious. Several texts describe the care taken in sorting and using cobalt. Special groups of workmen were dedicated to selecting blue, so as to ensure that good colour would ensue. After initial processing, imported pigments were painstakingly pounded in a mortar, about one-fifth being selected as first and second quality and a further twentieth as being usable after further levigation.[257] Decorators were very skilled, the best being tested both for skill and for economy of materials' use. Thus three artisans were given one *chin* 斤 of cobalt each to see who could produce the most from it, with awards for the most copious. Careful control was kept of the distribution of all pigments including cobalt, which were distributed according to the size of wares being decorated. Each painter was also responsible for the colour quality of finished products.[258] Cobalt was so precious that the artisans who painted pots also did different parts of designs, depending on skill. Simple rings were done by one group who also finished pots by polishing them on the wheel. Workers who did outlines were taught those skills only, as were those who filled in colours afterwards. To ensure uniformity of products that were turned out in hundreds and thousands, outline painters and colourists occupied the same workshops. Seals, marks and inscriptions were the job for skilled calligraphers.[259] One of the popular songs sung by potters at Ching-te-chen immortalises the decorators' work:[260]

[254] *Chiangsi Sheng Ta Chih* (1597 edn), ch. 7, pp. 16b–17a; *Nan Yao Pi Chi*, pp. 323–5; *Chiangsi Thung Chih* (1880 edn), ch. 93, pp. 16b–17a.
[255] *Thao Shuo*, ch. 1, p. 6b.
[256] *Nan Yao Pi Chi*, p. 11b/332.
[257] *Thao Shuo*, ch. 1, p. 7a, quoting from *Shih Wu Kan Chu*.
[258] *Chiangsi Sheng Ta Chih* (1597 edn), ch. 7, pp. 16b–17a.
[259] Thang Ying's description no. 11, in *Thao Shuo*, ch. 1, p. 8a.
[260] *Ching-te-chen Thao Ko*, ode no. 9 in section on blue-and-white, see Yang Ching-Jung (1994).

Blue-and-white [strokes] thin and thick [flow from] the end of the brush
Painted across the broad expanses of porcelain blanks
Knowing that the Wei songs run in a winding style
Then [we] realise that the principle of glazing is the same.

青花濃淡出毫端
畫上瓷坯面面寬
識得衛風歌尙迥
乃知罩釉理同看.

The price and scarcity of good-quality cobalt meant that from the beginning of the Chhing period all-white wares were popular because they were the cheapest.[261] After the Chhien-Lung reign period the main source of cobalt was Yunnan province,[262] while for modern times, a detailed study of +20th-century usage of cobalt in Chinese porcelain shows a clear break that corresponds to the Second World War. Before this time high-manganese cobalt ores were in general use, while after the late +1940s low-manganese pigments were the usual type.[263]

Cobalt in Chinese Enamels and Glass

The cobalt ores, traditionally used for underglaze-painting in south China, were naturally and heavily contaminated with iron and/or manganese oxides. They were ideal for underglaze painting on porcelain as they modified the harsh blue of pure cobalt oxide in its concentrated state. Also, being much weaker colourants than pure cobalt oxide, the iron and manganese acted as useful 'extenders' that made the pigments' strengths during painting easier to assess. The converse of these advantages was that the underglaze-blue ores were unsuitable colourants for lead-rich glazes and glasses. Cobalts used for these materials therefore needed to be much purer than for porcelain painting. As it was impractical to remove iron and manganese oxides from 'underglaze' cobalt ores during processing, much purer sources of cobalt oxide had to be found in order to colour high-lead compositions to acceptable blues.[264]

This fact seems to have inhibited the use of cobalt-blue colours in lead-rich low-firing glazes in China during the +10th to +13th centuries. The problem was not so acute with northern lead-alkaline glazes of the +14th century, as the potassia-rich

[261] *Fu-liang Hsien Chih* (1682 edn), ch. 4, p. 46a.

[262] Watt (1979), p. 81, 83.

[263] Yap & Tang (1984), p. 78, note that of 50 examples studied: 'all the pieces before the War have Mn/Co ratios of 2.5 and above while all the pieces after the War have Mn/Co ratios of less than 0.7, only about 27% of which have a value greater than 0.2.'

[264] Cobalt ores can be refined by the difficult process of melting them within a potash-silica glass. The arsenic then: 'acts in combining with iron, copper or nickel to form a speiss, which settles at the bottom of the furnace, leaving a cobalt glass practically free from impurities at the top.' This process has been used in Saxony since the +16th century to produce *smalt*. Halse (1924), p. 11. See also Taylor (1977), pp. 7–8, who distinguishes clearly between zaffre (a crude mixture of calcined cobalt ore and sand) and true *smalt*, the refined cobalt-rich glass. However, it is possible that this process may not have worked properly with asbolites, as their high alumina and silica contents would have stiffened the potash-silica glasses substantially.

compositions were more tolerant of the iron and manganese impurities present in the cobalt pigments.[265]

In the Hsüan-Te reign period there was a rare use of a low-firing cobalt-blue monochrome glaze, but for some reason this colour was not added to the current overglaze-enamel palette. That style relied instead on touches of underglaze-blue, particularly on *tou-tshai* 鬥彩 wares. Moreover, aubergine enamel introduced during the Chheng-Hua reign for *tou-tshai* wares may well have used a manganese-iron-cobalt ore. Likewise the overglaze under-enamel black pigment, which made its first appearance at Ching-te-chen during the Chheng-Hua reign period, was also based on cobalt ore. From this time onwards both Ching-te-chen under-enamel black outlines, and Ching-te-chen aubergine enamels tended to exploit similar manganese-cobalt ores. It has been proposed that these +15th-century innovations may have represented unsuccessful attempts to make under-enamel blue pigments, and lead-rich overglaze-blues respectively. The black and aubergine effects that resulted were adopted nevertheless, and became established elements of the Ching-te-chen overglaze-enameller's repertoire.[266]

True lead-fluxed overglaze-blues became possible in the Chia-Ching reign period, when some cobalt ores used at Ching-te-chen were unusually pure. During this time lead-fluxed cobalt-coloured glazes were used both as low-firing monochrome glazes, and also as true overglaze-enamel blues. With a gradual return to high-manganese cobalt ores at Ching-te-chen after the Chia-Ching reign period, true overglaze-blue cobalt-coloured enamels again largely disappear from Ching-te-chen porcelain manufacture, perhaps returning in the mid +17th century on some rare enamelled transitional wares.[267] Overglaze-blue enamelling on porcelain during this period, however, was used far more successfully in Japan where the high-quality cobalt ore needed was apparently imported from Persia.[268] In China during the Chhing dynasty, cobalt also needed to be imported from diverse sources, and over considerable distances. Bernard Watney reported that in the later +18th century large quantities of cobalt were exported from Europe to China, quoting records of +1778 and +1795. The latter stated that, 'it was then difficult to get smalts in the pure state as the East India Company was exporting them to China.'[269]

THE METAL ENAMEL CONNECTION

We have already explored the links between enamels of the *famille rose* palette on ceramics and metal, and in particular the introduction of an overglaze-blue enamel that was prepared from ground blue glass (see pp. 651–2). Until this event in the Khang-Hsi reign period, ceramic and metal enamels had seen parallel, but

[265] Wood (1999), pp. 237–8.
[266] Henderson *et al.* (1989b), p. 322.
[267] Kilburn (1981), p. 180, no. 158, and colour pl. on p. 137. Butler (1985), pp. 51–2, pl. 27. Butler *et al.* (1990), p. 65, pl. 27. However, there are some doubts as to whether these particular pieces were made at Ching-te-chen or at Te-hua.
[268] Jenyns (1965), p. 124.
[269] Watney (1973), p. 1.

generally quite separate, developments in China. For example, lead-alkali silicate bases were used for metal enamels, rather than the simple lead-silicates used at Ching-te-chen. Chinese metal enamels also included a range of colours and qualities unexploited by porcelain enamellers at Ching-te-chen.[270] The sources of cobalt too seem to have varied among the cloisonné enamels used. The earliest Chinese cloisonné enamels so far studied (from the Hsüan-Te reign period of the +15th century) can show remarkably pure cobalt colourants (Table 141). Those colourants are often associated with tin oxide and arsenic, though occasional examples use the more familiar manganese-cobalt ores, particularly for blue-violet colours. Hsüan-Te period metal enamels also show evidence for fluoride opacification. Fluoride opacification has been a characteristic of Chinese glasses since the Thang dynasty, but has not so far been observed in Chinese overglaze enamels on ceramics.[271]

Thus +15th-century Chinese cloisonné enamels show their origins in traditional Chinese glass technology, by incorporating such typical post-Han dynasty features of glass construction as lead-potassia fluxed matrices and the use of calcium fluoride as an opacifier.

Some +15th-century cloisonné enamels are coloured with iron-cobalt pigments of such purity that the cobalt percentages may actually exceed the levels of iron. High levels of tin oxide are also a most unusual feature of these particular blue glasses, with the tin oxide seeming to correlate positively with the cobalt oxide+iron iron oxide contents. Tin levels are far lower where the cobalts used in the cloisonné enamels are of the high-manganese type, which again suggests that the tin oxide is associated with this particularly pure iron-cobalt material. No natural mixtures of iron, cobalt and tin are known, which suggests that the tin oxide may have been introduced during the cobalt's preparation. This may in turn suggest a West Asian origin for this unusually pure pigment.[272]

Blue cloisonné enamels, essentially similar to those of the +15th century, were used for cloisonné enamelling in the +17th century, although by now the cobalt source seems free from tin and from arsenic. The new Khang-Hsi period overglaze-blue porcelain enamel is of this 'cloisonné' lead-alkali type, which seems to support Père d'Entrecolles observation that Ching-te-chen blue enamel was made from a pulverised blue glass used as an enamel with metal, rather than from the usual mechanical mixtures of white lead and quartz (Table 142). We can speculate that the material was adopted because of the particular purity of its blue tone.

[270] Chinese metal enamels sometimes exploit fluoride and arsenic opacification, while opaque yellows were made from lead stannate, and opaque reds from cuprite crystallisation, see Henderson *et al.* (1989a), pp. 141–4. From this range of effects, only the lead arsenate-white and the lead-stannate yellow, appear in the new Ching-te-chen porcelain-enamel palette which seems to have been developed in the early +1720s.

[271] Werner & Bimson (1963), p. 303. Opacification itself (often from barium disilicate crystals) was used in Chinese glass from its earliest appearance, in the Warring States period.

[272] It is interesting that the paint pigment Cerulean blue, or *bleu céleste* is obtained: 'by heating together cobalt sulphate and alum, sometimes with the addition of zinc sulphate, tin oxide and precipitated silica or chalk.' Halse (1924), p. 12. Amongst other stable spinel-type compounds these calcined mixtures may have developed is the 4:2 spinel $Co(SnCo)O_4$. See Singer & Singer (1963), p. 231.

Table 141 *Chinese cobalt-blue cloisonné enamels of the +15th century*[a]

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	CoO	CuO	PbO	SnO_2	F	As_2O_5	BaO	Total
Hsüan-Te blue	46.1	0.2	0.6	1.4	-.-	13.8	0.2	0.0	0.86	0.03	35.9	0.7	-.-	-.-	-.-	99.8
Hsüan-Te blue	44.9	0.1	0.65	1.4	-.-	13.8	0.2	0.0	0.9	0.04	36.25	1.3	-.-	-.-	-.-	99.5
+15th-C blue	41.6	0.5	1.8	3.6	0.5	5.6	0.3	0.06	0.55	0.3	38.0	2.6	1.8	0.9	0.1	98.2
+15th-C blue-violet	37.0	1.2	1.3	2.0	0.4	11.6	0.3	1.5	0.1	0.1	41.5	0.2	1.3	0.0	0.0	98.5
+15th-C blue	41.0	1.4	1.5	3.1	1.8	5.6	0.5	1.0	0.05	0.3	40.0	0.2	0.5	0.0	0.0	97.0

[a] From Twilley (1995), p. 169, table II, and Biron & Quette (1997), p. 38, main table.

Table 142 *+15th- and +17th-century blue cloisonné enamels compared with a Khang-Hsi period overglaze-blue porcelain enamel from Ching-te-chen*

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	CoO	CuO	PbO	SnO_2	F	As_2O_5	Cl	Total
+15th-C cloisonné blue[a]	41.6	0.5	1.8	3.6	0.5	5.6	0.3	0.06	0.55	0.3	38.0	2.63	1.8	0.9	1.5	99.7
+17th-C cloisonné blue[b]	40.3	0.6	0.1	3.4	0.1	6.4	6.1	0.1	0.7	0.0	40.1	0.0	-.-	0.0	1.1	99.0
Khang-Hsi porcelain blue enamel[c]	42.1	0.4	0.3	0.9	0.04	6.2	0.45	0.0	0.2	0.15	47.8	0.0	-.-	-.-	1.6	100.1

[a] Biron & Quette (1997), p. 38, main table.
[b] Henderson *et al.* (1989a), p. 137, table 1.
[c] Kingery & Vandiver (1985), p. 376, table 2.

Table 143 *Types of cobalt used in Chinese ceramic glazes, underglaze pigments and cloisonné enamels (showing major colouring components)*

Type of ware	Fe	Cu	Mn	Sn	Ni	Co
Warring States glazed beads (north China)[a]	✓					✓
Han dynasty glass (south China)[b]	✓		✓			✓
Thang dynasty *san-tshai* glazes[c]	✓	✓				✓
Thang dynasty underglaze-blue pigment[d]	✓	✓				✓
Thang dynasty underglaze-blue pigment[e]		✓				✓
Yuan dynasty underglaze-blue (Ching-te-chen)[f]	✓					✓
Hung-Wu period underglaze-blue (Ching-te-chen, best)[g]	✓					✓
Hung-Wu period underglaze-blue (Ching-te-chen, folk)[h]			✓			✓
Ming dynasty and Chhing dynasty underglaze-blue pigment[i]			✓			✓
Fa-hua glazes, Ming dynasty, north and south China[j]			✓			✓
+15th century cloisonné enamel[k]	✓			✓		✓
Chhing dynasty porcelain enamel[l]	✓					✓
Chhing dynasty metal enamel[m]						✓
Lu-chiin glazes[n]	✓				✓	✓

[a] Brill *et al.* (1991), pp. 50–1, table 1.
[b] Zhang Fukang *et al.* (1986), pp. 93–4, tables 2 and 3.
[c] Li Guozhen *et al.*, (1986), p. 78, table 2. Li Zhiyan & Zhang Fukang (1986) p. 69, table 1.
[d] Chen Yaozheng *et al.* (1995b), p. 205, table 15–5.
[e] *Ibid.*
[f] Chen Yaocheng *et al.* (1986).
[g] Chang Chi-Kang *et al.* (1999), p. 242, table 1.
[h] *Ibid.*
[i] Chen Yaocheng *et al.* (1985), pp. 307–8, table 15.7.
[j] Wood *et al.* (1989), p. 174, table 1.
[k] Twilley (1995), p. 169, table II.
[l] Kingery & Vandiver (1986), p. 370, table 2.
[m] Henderson *et al.* (1989), p. 137, table 1.
[n] Developed from Wood *et al.* (2002), p. 351, table 6.

One familiar feature of blue porcelain enamels of the Khang-Hsi period was a tendency for iridescent halos to form around the blue colours during firing. This has been attributed to chlorine in the enamel encouraging some lead from within the enamel-glass to vaporise during firing, with the lead condensing around the blue enamel as a thin iridescent film.[273] Similar levels of chlorine can be seen in both +15th- and +17th-century blue cloisonné enamels,[274] and also in the Khang-Hsi period overglaze-blue.[275] High chlorine levels can occur in Chinese glasses as early as the Warring States period, perhaps from the use of rock salt in the original glass-batches.[276]

[273] Wood (1999), p. 241.
[274] Biron & Quette found chlorine levels between 0.8% and 2.2% in all 36 examples of cloisonné enamel glasses dating from the +15th and +16th centuries. Biron & Quette (1997), pp. 38–9, table.
[275] Kingery & Vandiver (1985), p. 370, table 2.
[276] Zhang Fukang (1986a), p. 26.

Opaque glasses, similar to those used on Chinese cloisonné enamel wares, were also used to make some Chhing dynasty Ching-te-chen monochrome porcelain glazes, particularly the *lu-chün* 爐鈞 'robin's egg' glazes, made at Ching-te-chen from the late +1720s onwards. The overall composition of one sample of this glaze proved close to the kind of arsenic-opacified enamel used on Chinese cloisonné ware of the +17th century, while its cobalt pigment appeared to be high in nickel and iron – a rather exceptional result (see pp. 649–50).[277] This may suggest that this cobalt pigment was imported from Europe or from Persia.

In some ways, this adoption in the Chhing dynasty of blue cloisonné-type glasses for the making cobalt-blue porcelain overglaze enamels and low-firing monochrome glazes, brings the story of cobalt usage in China to full circle as the earliest cobalt-bearing glazes used in China were also derived from contemporary glass technology.

As to the types of cobalt used in China, we can now see that these are among the most varied in any world ceramic tradition. Analysis has shown the use of high-copper, high-iron, high-manganese, high-nickel and high-tin examples at various times in China's ceramic history (Table 143).

Even so, it is embarrassing at present to admit that we are sure of the ultimate origin of only *one* type of cobalt ore used in traditional Chinese ceramics, namely the native high-manganese variety that is so thoroughly documented in both geological and practical texts.

In terms of application, it is perhaps China's use of cobalt as an underglaze pigment on porcelain that represents her greatest contribution to the use of the material in world ceramics. Chinese blue-and-white porcelain became the most widely traded ware in world history, and stimulated blue-and-white production in countries as various as Persia, Italy, Syria, Turkey, England, Saxony, Denmark, Vietnam, Korea and Japan. Ching-te-chen blue-and-white is also one of the most fertile repositories of form and ornament in the whole of Chinese ceramics, where it records some of the most complex cultural interactions between East and West that have occurred in the history of design. The ramifications of China's influence in these realms will be explored more fully in Part 7 of this volume.

[277] Wood *et al.* (2002), pp. 349–51.

GILDING

THE USE OF METALS TO ENHANCE CERAMICS

The idea for using gold to enhance the appearance of ceramics is an approach to ornament of surprising antiquity. The technique appears in some remarkable Neolithic earthenwares from the -5^{th} millennium site at Varna in Bulgaria, where dishes and jars were dusted with alluvial gold dust, which was then burnished on.[278] A similar method, again using gold dust, was used in Mesopotamia at Ur and Tepe Guara where some gilded ceramics are also dated to the -5^{th} millennium.[279] These techniques pre-date the use of sheet-gold to enhance the surfaces of artefacts by more than 1,000 years.[280]

Writers on the use of gold to enhance ancient objects make a distinction between gold foil and gold leaf. The former is thicker, self-supporting and often attached by fine rivets, or secured in groves on the object to be gilded. Gold leaf by contrast is a flimsy material with a tendency to fold back and stick to itself through electrostatic attraction. It may be as thin as 0.1–0.2 microns[281] and is usually applied with an adhesive to non-metallic grounds, and directly, without an adhesive, to metals. Gold foil appears on Egyptian artefacts of the Old Kingdom period (–3,100 to –2,400), but the earliest identification of true leaf-gold is currently on an Egyptian papyrus of the -14^{th} century.[282]

The use of gold in ancient China seems far more limited than in the Near East, and gold-rich finds such as the tomb of Tutankhamen, uncovered in +1922 and containing about twice as much gold as in the Royal Bank of Egypt at the time, have no parallels in China.[283] Examples of gold-foil and gilding in the early archaeological record in China are both rare and widely distributed, but an early use of gold detail appears on a bronze *chüeh* 爵 of the Erh-li-thou 二里頭 period (*c.* –1,600).[284] On the thread-band ornament around the *chüeh*'s body the thin gold sheet has been attached with red lacquer.[285] In south China, in Szechuan province, the collection of 54 bronze heads from the mysterious Shu kingdom 蜀国 (*c.* -12^{th} to -10^{th} centuries) included two heads partly covered with gold foil, and an entire gold sheaf on a wooden core. Robert Bagley notes further examples of Shang-period bronzes ornamented with gold, but points out that:[286]

[278] Eluère & Rab (1991).
[279] Pernicka (1990).
[280] Oddy (1993).
[281] A micrometre or micron is one-millionth of a metre.
[282] Found, appropriately, on a manuscript commemorating the 'chief of makers of thin gold'. See Alexander (1965), pp. 48–52. The authors are grateful to Kilian Anheuser's D.Phil. thesis for these four references to the early uses of gold in ornament.
[283] Tutankhamen's tomb is dated to –1,350.
[284] Now in the Museum of East Asian Art, Bath, see McElney (1993), p. 27.
[285] Illustrated in Yang Xiaoneng (1999), pp. 211–14, 226–7.
[286] Bagley (1987), p. 41.

The painted, gilded and inlaid Bronzes of Eastern Zhou [Chou] and Han have little precedent in the Shang period . . . There are only a few exceptions to mention. Andersson examined one Shang axe of unknown provenance, which seems to have been mercury gilded in antiquity, and a *gui* [*kuei*] 簋 in Copenhagen is described by Leith as partly gilded.

The reference to mercury gilding in this passage raises the question as to when the gilding was applied, as the technique is believed to have started in China, and in the world, in the –3rd century.[287] Mercury gilding, sometimes called 'fire gilding', exploits the way that gold and mercury can be alloyed to make immiscible pastes.[288] Such Hg-Au amalgams are summarised by Kilian Anheuser, who has reproduced the techniques successfully at Oxford, and studied their history in detail:[289]

Amalgam gilding, also named fire gilding or mercury gilding . . . was carried out in two different ways: either by applying a paste of gold amalgam and mercury on to a thoroughly cleaned base-metal surface (copper, copper alloy or silver), or by first applying a layer of pure mercury to the base metal on to which gold leaf was laid, forming an amalgam *in situ*.

For both approaches heat is applied to drive away the mercury, after which the dull and porous gold can be burnished flat. Anheuser's work questions two long-held assumptions concerning the heating stage of the process. The first was that it might be possible to dispense with heating altogether and to let the mercury evaporate naturally. The second was that heating to the boiling point of mercury (357°C) was necessary, and generally practised. Anheuser's experiments showed that heating to between 250°C and 350°C was both necessary and effective; at temperatures lower than this far too much mercury remained in the gold, while temperatures higher than 350°C spoiled and discoloured the gilding.[290]

Silver sometimes replaced gold in these mercury-based amalgams, although, for 'silvering' to work properly, the paste had to be applied to an initial coat of gold. Anheuser examined eight examples of Chinese silvering from the late Eastern Chou and Western Han dynasties, and found: 'in all cases without exception silver amalgam was applied over a layer of fire gilding.'[291] Silver in ancient China was as rare as gold, and a fashionable material at a time when bronze form and ornament had evolved from the powerful and disturbing character of Shang and Western Chou dynasty ritual vessels, to the more decorative and luxurious styles of the Eastern Chou period.

In a few rare cases the spectacular silvered bronzes of the Warring States period were copied in ceramics. This phenomenon is represented by a group of three

[287] Oddy (1991). However, Needham & Lu Gwei-Djen (1974), p. 248, speculate that the technique might have been slightly earlier: 'for China this could most probably be placed in the Warring States period, perhaps some time before the life of Tsou Yen 騶衍 in the –4th century, when the properties of mercury were first explored.'

[288] Typically 80%+ mercury. The paste consists of gamma-gold amalgam (Au_2Hg) particles dispersed in mercury.

[289] Anheuser (1996), p. 9 who notes that a mercury salt solution (for example, mercuric nitrate) could also be applied as this 'releases metallic mercury in an electrochemical reaction with the base metal'.

[290] *Ibid.*, p. 82.

[291] *Ibid.*, p. 74. This confirmed earlier observations of Oddy *et al.* (1979), La Niece (1990), and Bunker *et al.* (1993).

unglazed Warring States earthenware vessels from Hunan province, covered with tinfoil and described and analysed by Isaac Newton in +1958.[292] All three vessels were made in the cast-bronze style, one in the form of a spherical *tui* 敦, the others copying round and square sectioned *hu* 壺. Black and brown materials were found beneath the tin-foil surfaces and these gave faintly resinous results on analysis, while microscopic analysis of an etched sample of the tin foil showed the characteristic grain-structure of a material that had been thinned by hammering or rolling, in this case to about 0.05 millimetres. The tin foil had been applied to the outsides of the vessels and then rubbed or lightly burnished to eliminate wrinkles. In the case of the *tui* vessel, its tin surface had been treated with a sulphide wash to suggest bronze or gold, while the thin layers of tin applied to the large wine vessels had been polished to appear like silver. Nonetheless, the 'silvered' burial ceramics found in Hunan province probably rated low in China's material hierarchy, playing roles rather similar to modern theatrical props, and comparable to the plain lacquered burial earthenwares from the Western Han period, discovered in northern China.[293]

Analysis of the tin material on the vessels from Hunan province proved difficult because of the smallness of the sample tested, but an incomplete result of 95% tin and 1% antimony was recorded. However, this process was not a new one: it had been anticipated in Greece during the -14^{th} to -13^{th} centuries when tin foil was occasionally used to enhance unglazed ceramics, using resin or some similar organic binder as an adhesive.[294]

Metal Forms and Ceramics

The Hunan province ceramics covered in tin are extreme examples of a tendency that runs through much of China's ceramic history, i.e. the imitation in ceramics of vessels originally made in metal. As the number of metal vessels excavated in China (and beyond) has grown, and ceramics from the world's collections have been compared with them, the debt that Chinese potters owed to metalwork has become more obvious. As a result it is now appreciated that Chinese ceramics were at least as strongly influenced in their forms by metal prototypes as were the ceramics of classical Greece and the early Islamic world.[295]

While possible influences of metal forms on some Neolithic wares from Shantung province are still debated, the effect of metal on ceramic design becomes evident during China's Bronze Age. At that time, both glazed and unglazed ceramics were made in the style of contemporary cast-bronze vessels.[296] In its most direct manifestation this cast-bronze influence on ceramics lasted until at least the $+3^{rd}$ century and, in its archaistic form, from about the $+12^{th}$ century to the present day. Shang

[292] Newton (1958), pp. 9–12 and figs. 4–6. See also Newton (1951), pp. 56–69.
[293] Wang Zhongshu (1982), figs. 183–5 (figs. unpaginated).
[294] Gillis (1994), pp. 57–61.
[295] A survey of metal's influence on many world ceramic traditions may be found in Vickers (1986).
[296] See particularly Yuba (2001), pp. 52–5.

dynasty bronze vessels in particular have cast long shadows forward through the applied arts of China: not only in ceramics, but also in the shapes adopted for vessels made in hardstone, softstone, cloisonné, lacquer and glass.

During the +5th and +6th centuries imported vessels from the West, made from beaten silver or gold, began to influence Chinese metal-working practice and eventually those forms and their decorative treatments were reinterpreted in Chinese ceramics.[297] In the Sung and Yuan periods metal forms were often used in ceramics, either because the ceramics served as a cheaper substitute material, or because the function of vessels (for example, on altars) was one traditionally served by bronze or precious metals.[298] By the +14th to +16th centuries beaten and cast vessels from the Near East were used as prototypes for many Ching-te-chen porcelains, and a number of these medieval Islamic shapes survive in Chinese ceramics today.

GOLDEN RIMS

Deep golden rims occur on many Chinese silver vessels of the +6th to the +10th centuries, where they embellished and enhanced the forms. This feature appears particularly on the top-quality silver-gilt vessels recovered from the crypt of the Fa-men temple, which were inventoried in +874 and rediscovered in +1984 when the pagoda above the crypt collapsed. Many contemporary metal vessels in China also bore gilded rims and feet, and it seems that such examples gave rise to the practice of applying deep metal bands to the rims (and sometimes the foot-rings) of Chinese ceramics. Gilded finials were even applied to some fine vessels made from jade.

The style became well established in the +9th to +10th centuries, when it appears on ceramics found in the tomb of one of the rulers of the Wu-Yüeh kingdom 吳越国 in Chekiang province. At this site both northern whitewares and southern greenwares of quite exceptional quality were found, some copying silver forms exactly. Many were bound at both foot and lip with gold and silver, and some were inscribed *kuan* 官 (official) or *hsin kuan* 新官 (new official).[299] This practice of binding the rims (and sometimes the feet) of ceramic vessels with metal continued in China in the +11th to the +14th centuries, when deep metal rim-bands were often used to strengthen and enhance the appearance of high-quality stonewares and porcelains in both north and south China.[300]

[297] 'Such foreign imports not only stimulated an interest in gold and silver as appropriate materials for fine eating and drinking vessels, but also established in China a range of foreign vessel shapes, including stem-cups, cups with flanged handles, lobed bowls and slender ewers, and a series of foreign decorative schemes, among which centrally placed animal designs are the most conspicuous.' Rawson (1986), p. 34. See also Rawson (1989) for a discussion of Chinese silver and its influence on porcelain development.

[298] Kerr (1990), pp. 39–41.

[299] Rawson (1986), p. 39.

[300] Ts'ai Mei-Fen (1996) discusses the binding of Ting ware rims with metal.

FIRED ON GILDING

While applied rim-bands and foot-bands of beaten metal were not hard to manage with conventional metal-working methods, detailed gilded patterns, evoking gold-inlay or partial mercury-gilding, presented greater challenges to the makers (or the enhancers) of ceramics. Gold leaf, for example, soon rubs off hard porcelain and stoneware glazes in everyday use. Fired-on gold is more stable than simple gilding, but the technique involves some technical problems, the resolution of which has taxed the inventiveness of potters for centuries in many ceramic cultures and traditions.

It is possible in practice to apply gold to ceramics as leaf, foil or dust and to fire to a high enough temperature to fuse the gold to the ceramic substrate. Hainbach describes such a technique in +1907 for achieving matt gold:[301]

> Matt gold, *i.e.* gold that is not burnished after firing, is produced by applying a mixture of gold and silver, without any flux, and firing at a high temperature, or by intimately triturating finely ground pure gold leaf with oil of turpentine, applying the mixture with a brush and firing at a high temperature.

The difficulty here is achieving the right temperature, which depends to a large extent on the softening temperature of the glaze beneath. For example, gold applied to overglaze enamel may be fired to as low as 600°C, and for a porcelain glaze to more than 800°C.[302] If kiln temperatures are too low the gold will simply rub away after firing, while if the kiln is overfired the gold will tend to form fine beads as its melting-point is exceeded and the definition of the gilding will be compromised. Most ceramic traditions that use overglaze-gold employ draw-trials to tell when the gold is sufficiently bonded with the ceramic substrate, be it enamel, glaze or hard-fired porcelain.

When using gold in its powdered state to decorate ceramics by painting, the fineness of the gold powder and its thorough dispersion within the painting medium are essential conditions for success. As Hainbach stresses:[303]

> The noble metals for use on porcelain must always be in a very fine state of division, so fine, indeed, that it can only be obtained by chemical means.

Nonetheless it does appear that skilful mechanical grinding of gold leaf may sometimes achieve this state, without the need for chemical solution and precipitation. Kenneth Shaw describes the conversion of gold leaf to 'mussel gold' or 'shell gold'. This was a form of gold used in manuscript illumination and in pottery decoration, and which took its name from the mussel-shells in which the prepared material was once sold:[304]

[301] Hainbach (1907), p. 198. However, Tomimoto Kenkichi 富本憲吉 often made fired-on gold by mixing powdered gold and a thick glue solution and firing this to the point where the gold would not rub away from draw-trials. This gold was burnished after firing. See Sanders (1967), p. 233.
[302] Sanders (1967), p. 223; Shaw (1962), p. 71.
[303] Hainbach (1907), p. 189.
[304] Shaw (1962), p. 62.

Mussel gold, of which, we are told a skilled workman could prepare only 60 grams a day, was . . . used to decorate only expensive porcelain. In its preparation, gold leaf was rubbed with honey, sugar (or mucilage) and sea salt on a glass plate, until a suitable state of division was obtained. The whole blend was then digested in warm water and washed. It is apparent that the job was extremely skilled and difficult.

This can be compared with Père d'Entrecolles' account of the preparation of gold for decorating porcelain at Ching-te-chen:[305]

When one wishes to apply gold, one grinds it and mixes it at the bottom of a porcelain vessel until one sees a little cloud of gold in the bottom of the water. One allows it to dry and then uses it by mixing in a sufficient amount of gummed water. With thirty parts of gold one incorporates three parts of white lead, and then one applies it to porcelain, just like a coloured glaze.

In his second letter, Père d'Entrecolles mentions gold leaf specifically in the preparation of the gold suspension used for fired-on gilding, and again notes the use of a lead carbonate flux addition. He records that silver leaf was prepared in a similar way but, during firing:[306]

the pieces in silver should be removed before the ones in gold. Otherwise the silver will vanish before the gold has reached its shiny state.

The Japanese potter Tomimoto Kenkichi 富本憲吉, who worked in a modern *kinran-de* 金襴手 style[307] in Japan after the war, also stressed this important difference between the firing of overglaze-silver and overglaze-gold. This difference must reflect the respective melting-points of silver and gold (Ag 960.8°C and Au 1,063°C),[308] and also some tendency for silver to volatilise somewhat in the kiln.[309]

At one point in his letters Père d'Entrecolles remarks that the Chinese were unaware of strong mineral acids such as hydrochloric acid and nitric acid,[310] a point

[305] Tichane (1983), p. 84, translation of Père d'Entrecolles letter of +1712. D'Entrecolles subsequently dated the introduction of fired-on gilding at Ching-te-chen to about twenty years before his +1722 letter: 'They say that it has only been about twenty years since they've found the secret of painting with *tsoui*, or violet, and of gilding porcelain.' *Ibid.*, p. 117. The +17th-century revival of the Ching-te-chen overglaze-blue is certainly earlier than +1700, see Kilburn (1981), p. 180, no. 158, and colour pl. on p. 137; Butler (1985), pp. 51–2, pl. 27; and Butler *et al.* (1990), p. 65, pl. 27. Dating the first regular and successful use of fired-on gilding at Ching-te-chen presents more of a problem (see below pp. 703–7).

[306] Tichane (1983), p. 124, translation of Père d'Entrecolles latter of +1722. For an analytical and statistical study of the use of silver on Ching-te-chen Chhing dynasty porcelains (particularly export wares), see Mueller (2001). Mueller (2001) found about 16% lead-to-silver on the silver decoration of a Chhing saucer, using energy dispersive X-ray microchemical analysis (EDS) in a scanning electron microscope (SEM). Mueller also suggests (2002, p. 46) that porcelain was resilvered in Europe to enhance its appearance, in the same manner that export ware was regilded (see below p. 706).

[307] *Kinran-de* means 'gold brocade'.

[308] Kaye & Laby (1957), pp. 109–10.

[309] Sanders (1967), pp. 224–5. Tomimoto Kenkichi found that adding gold and platinum to the silver, allowed both gold and silver to be fired to the same temperature, with the bonus that silver-gold-platinum mixtures tend not to tarnish.

[310] Discussing the refining of copper and silver, Père d'Entrecolles notes: 'I think that if nitric acid were used to dissolve the copper, this copper powder would be more suitable for making the red which I spoke about [i.e. the high-temperature copper-red glaze]. But the Chinese don't know the secret of nitric acid and aqua regia [the hydrochloric-nitric acid mixture used for dissolving gold], their inventions being of extreme simplicity.' Tichane (1983), p. 119, translation of letter of +1722.

also noted by Needham.[311] Acids of this type have long been important in Western alchemy and chemistry, where they played vital roles in the refining of gold, in the preparation of impalpable gold dusts and, later, in the preparation of materials such as 'purple of Cassius' (see p. 636). From the early +18th century onwards most Western techniques used for preparing gold for decorating ceramics used these powerful acids at some stage in their process.[312] Initially this was for preparing fine and pure gold dusts but, from the late +19th century onwards, these strong acids were involved in the creation of the almost alchemical mixtures of gold salts, sulphur-turpentine balsams and aromatic oils, that are known today as 'liquid-bright' golds. These are the usual preparations for decorating modern Western pottery and porcelain, where they fire to shiny surfaces without the need for burnishing.[313] 'Liquid-bright golds' have no parallels in traditional Chinese practice, although they are now used widely in China's modern ceramic industry.

Returning to traditional Chinese methods for gilding, mercury gilding, at its usual operating temperature of 250°C to 350°C, does not seem to have been used for decorating ceramics. The technique depends to some extent on a reaction between the Hg-Au amalgam and the copper, bronze or brass beneath, and seems difficult to use even with iron and steel. Nonetheless, at the *higher* temperatures used for firing overglaze-gold (*c.* 700° to 1,060°C) mercury gilding may play some part in the

[311] Needham & Lu Gwei-Djen (1974), p. 38, write: 'use of nitric acid (*aqua fortis*) or nitric and hydrochloric acid together (*aqua regia*), was presumably unknown to any ancient or medieval people, since the discovery of the strong mineral acids has to be placed towards the end of the +13th in Europe.' While accounts of the 'solubilisation' of gold as iodocomplexes by reaction with naturally occurring iodates and iron (II) sulphate are described in two +6th-century Chinese 'protochemical' recipes. See Butler *et al.* (1987). Kilian Anheuser believes that 'there is no indication that the solutions were ever used for the gilding of metalwork.' Anheuser (1998), p. 10.

[312] An attempt has been made to distinguish mechanically ground from chemically precipitated gold in the overglaze decoration of some early Japanese porcelains, the assumption being that precipitated gold would be much finer. The techniques used were PIXE and SEM microprobe analysis. However, the results were ambiguous, i.e. both flaky and superfine (500–1000 nanometres) particles of gold were observed in the same areas of ornament, showing morphological aspects of both techniques. Lead was shown to be present at a substantial level. Jarjis *et al.* (1995), p. 147.

[313] Hainbach (1907), p. 193, notes the recent introduction of 'bright gold' to the European ceramic industry and explains: 'The proportion of gold that it contains is about 12 per cent, together with about 1 per cent of rhodium based on the weight of gold present. This latter metal is the cause of the gold becoming bright without burnishing, when fired . . . The alloy of gold and rhodium is in the form of a compound (auroterpene sulphide) which is readily soluble in ethereal oils.' However, S.G. Tumanov of the Dulev Colour Works, Russia, who has studied these organic gold compounds in detail, believes that much about their chemistry remains unexplained: 'Budnikov considers that the $C_{10}H_{16}S$ gives a double compound with gold chloride of the type $C_{10}H_{16}S.AuCl_3$ which upon heating decomposes to $C_{10}H_{16}Cl_2$ and gold sulphide. The gold sulphide with further heating, changes to Au and SO_3. Chemnizius assumed that the gold resinate is colloidal Au_2S_3 with a protective layer of an unknown component of sulphur balsam, Troitskii, by treating the gold resinate with acetone, separated from it fractions corresponding to $C_{10}H_{16}S_2Au_2$ . . . In particular, the reaction of forming gold resinate in his opinion should be considered as a reaction between the sulphur of the sulphur turpenes and the gold, completed owing to the free valency of the sulphur.' Tumanov, translated in Shaw (1962), p. 71. Tumanov gives firing temperatures for bright liquid gold as: 790–830°C on hard-porcelain glazes, 760–790°C on earthenware glazes, 540–600°C on soda-lime glasses, and 430°C on lead-crystal glasses (*ibid.* pp. 73–4). The softening temperatures of the underlying glazes or glasses therefore seems to be the key condition for the successful firing of 'liquid bright gold'.

gilding of ceramics, as a version of the method is described in a chemical encyclopaedia of +1877. The article notes that: 'The gold (which is prepared with quicksilver and flux), when ready for use appears as a black dust.' The account continues with an account of the 'watches' (draw-trials) that are used to:[314]

> ascertain the degree of heat at which the gold becomes attached without altering the tints of the hues', i.e. the other enamel-colours in the kiln.

This latter remark suggests that the typical firing temperatures associated with on-glaze gold may be used with amalgam gilding, once the mercury had been driven away. Although mercury gilding would have been helpful in the initial dispersion of the gold, the fired gold would have needed thorough burnishing to consolidate the dull and porous layer produced.

All the above suggests that some seven quite different approaches to the gilding of ceramics could have been used in China, based on known Chinese methods for handling gold. These divide broadly into the unfired and the fired:

UNFIRED

- Gold leaf, perhaps with an adhesive (such as lacquer) between glaze and leaf.[315]
- Powdered gold applied with a glue or lacquer medium.

Unfired gilt decoration on ceramics was not common, but was used on the most expensive painted burial wares of the Thang dynasty.

FIRED TO CONVENTIONAL OVERGLAZE-GOLD TEMPERATURES (*C.* 600–800°C)

- Powdered gold plus a ceramic flux.
- Mercury gilding plus a ceramic flux.

FIRED TO 'HIGH' OVERGLAZE-GOLD TEMPERATURES (*C.* 800° TO 1,060°C)

- Mercury gilding with no flux.
- Gold leaf with no flux.
- Powdered gold with no flux.

[314] Anon. (1877a), pp. 720–1.

[315] In addition to metalwork and ceramics, gold was commonly applied as a surface embellishment for sculpture. In the Sung and Chin dynasties, for example, gold leaf or gold paint were applied over a bole of kaolin and vermilion paint, while in the Ming dynasty fine water gilding was applied over bole and gesso. See Larson & Kerr (1985), pp. 60–4, 71–2.



Fig. 156 Thang dynasty burial figure, early +8th century



Fig. 157 Detail to show painted and gilt details of robes

All seven techniques would have needed burnishing at the final stage, usually managed with a smooth stone such as agate.

It is with these seven options in mind that any technical studies of the gilding of Chinese ceramics have to be considered. In addition, there is also the very important consideration that golds containing elements other than silver (for example, copper and iron, which are common contaminants or adulterants of natural gold) could only be used for unfired gilding. As Hainbach notes:[316]

> It is essential that chemically pure gold should be used [for overglaze-gold], since the presence of even minute traces of foreign metals will prevent the formation of a true gold colour, spoiling the tone and causing changes due to oxidation.

STUDIES OF GILDING ON CHINESE CERAMICS

Gilding and silvering were both used on some Ting wares 定窯, particularly the rarer types that bear lacquer-like black and brown glazes, i.e. 'black Ting' and 'red Ting'. The use of gold leaf has been identified in one red Ting example, where there is a suspicion that the gold ornament may have been contemporary with the bowl, and perhaps also fired on, as Robert Mowry writes:[317]

> The recovery of a russet glazed Ding [Ting] bottle with traces of gold decoration from a presumed Song [Sung] context in Hefei [Ho-fei 合肥], Anhui province attests to the antiquity of such wares. In addition the late Song literatus Zhou Mi [Chou Mi 周密] (1232–1298) remarked in his *Zhi yatang zachao* [*Chih Ya Thang Tsa Chhao*] that '[For] Ding bowls with gold decoration, garlic juice was used to prepare the gold, [which was then painted on]; after that the bowls were placed in the kiln and fired again; [the gold] will never come off.'

Fired-on gilding, using gold applied with gum, may also have been used during this period for enhancing glazed Persian stone-paste-wares. Abu'l Qasim wrote of the technique in +1301:[318]

> Each of these [the decorated objects] is put in an earthenware capsule into the gilding furnace, specially made for the purpose, and fired from morning to night at low heat. When they are fired the fire is made smaller and the firebox sealed with clay. All gilded pieces such as writing, etc. are made this way.

Returning to Ting wares, it is interesting to note in passing that garlic oil was used as a painting medium for on-glaze gold at Sèvres in the +18th century.[319] In the case of the red Ting ware bowl it may be that layers of gold leaf were superimposed before they were cut into the patterns used for decoration. A single leaf would have given too thin an effect after firing, while gold leaves stick together electrostatically and

[316] Hainbach (1907), p. 190.
[317] Mowry (1996), pp. 108–10.
[318] Allan (1973), p. 115.
[319] Pers. comm. Antoine d'Albis with NW (1998).

can easily be welded by firm rubbing. Alternatively a material nearer to foil may have been used.[320]

Besides this use on Ting wares, gold was also added to reserved, unglazed areas of celadons from Lung-chhüan in the +14th century, and to +14th-century porcelain from Ching-te-chen. Sumptuary regulations to control the use of gilding during the Yuan dynasty have been mentioned in Part 2 on p. 202. Examples of gilded wares from this time include a number of pieces preserved in hoards. Vessels in metal forms with monochrome blue glaze from the 'Pao-ting 保定 hoard' in Hopei province used gold to add extra features of decoration on parts of the porcelain ground that had been left blank to receive it.[321] Two more hoards, one at Kao-an 高安 in Chiangsi province and the other in Hang-chou 杭州 in Chekiang province, also contained showy vessels with gold-painted designs.[322] In addition to pieces preserved in buried caches were some rare Yuan dynasty turquoise-glazed wares that were also gilded, perhaps in imitation of Near Eastern silver lustre which has a rather golden hue. The turquoise examples occurred in Yuan dynasty strata at the imperial kiln site in Ching-te-chen.[323] Further rare Yuan dynasty white porcelain stem-cups found in excavations, were embellished with both overglaze enamels and gilding.[324]

Early +15th-century Ming dynasty monochromes were enriched with gilding, which has often worn away. However, a Yung-Le period underglaze-blue bowl in the National Palace Museum in Taipei still shows its gilt patterns.[325] In the Chheng-Hua reign period finds from the imperial kiln at Ching-te-chen included several items with white dragons reserved in a blue ground, in which the white glazed dragons were originally gilded, a new development.[326]

Some of the most elaborate examples of porcelains enhanced with gold were made at Ching-te-chen in the Chia-Ching reign period. The most spectacular pieces used dense gold patterns, usually floral in character, applied to grounds of contrasting colour. These grounds were often red enamels, but sometimes plain white glazes. These sumptuous gilded porcelains were much appreciated in West Asia, and also in Japan where the name *kinran-de* was adopted. There is often more gold than ground evident in Chia-Ching period *kinran-de* porcelains and it was once assumed that the entire area bearing gold ornament was first gilded overall, and

[320] Tomimoto Kenkichi used five layers of gold leaf for his on-glaze '*kinran-de*' effects in the +1960s. See Sanders (1967), p. 223. Two clues to the use of gold leaf in the decoration of the red Ting bowl are: (i) The observation that, at one point the design can be seen to have folded back on itself slightly, and (ii) that the three floral panels of gold are identical. See Mowry (1996), p. 110. It is suggested there that this similarity may have been achieved by some form of printing. However, cutting the image from a stack of gold leaves, and then dividing the stacked leaves into three, may be another explanation for these observed similarities.

[321] Chao Chü-Chhuan & Ho Chih-Kang (1965). One vessel, a *chüeh* 爵, is well illustrated in Wang Chhing-Cheng (2001), pl. 244.

[322] A white bottle from Kao-an, painted with a dragon in gold, is shown in Wang Chhing-Cheng (2001), pl. 248. For Kao-an, see also Liu Yü-Hei & Hsiung Lin (1982).

[323] Liu Xinyuan (1993), pp. 33–5; Liu Xinyuan (1992), p. 49.

[324] One such stem-cup is in a private collection, the other was excavated in Inner Mongolia and is currently on display in the Shanghai Museum. Both are illustrated in Wang Chhing-Cheng (2001), pls. 245, 246.

[325] Valenstein (1989), p. 168; Liu Hsin-Yüan (1993), pp. 44, 84.

[326] Liu Hsin-Yüan (1993), pp. 44, 84, fig. 19a.



Fig. 158 Pair of porcelain bowls with *kinran-de* 金襴手 designs, Chia-Ching reign period

then the gold was carefully cut away with a needle-point to create the pattern and to expose the background. In fact microscopic examination of one Chia-Ching example has revealed a rather different technique, as identified by Naitō Tadeshi:[327]

> Small pieces of gold foil were cut exactly to the parts of the pattern which were to appear in gold. These pieces were then made fast by an adhesive to the surface of the vessel. This was done with such exactness that the naked eye cannot detect the junctures of the separate pieces . . . Occasionally the parts are seen to be separated by minute spaces, or to overlap slightly . . . Examination also reveals the sharp-cut outlines of the pattern, quite different from the effect obtained by brush stroke.

Naitō was not sure of the adhesive used, but suggests Chinese lacquer, 'which retains its effectiveness for several hundred years. Only exposure to direct sunlight weakens it.' Naitō's own macro photographs reveal that a few minor details appear to have been achieved with a needlepoint, used to cut through the gold to the ground beneath.[328] When copied in Japan, the *kinran-de* technique was more often managed with fired-on gilding, as exemplified by the work of the +20th-century potter Tomimoto Kenkichi whose virtuoso *kinran-de* style porcelains were made in the +1950s and +1960s.[329]

[327] Naitō (1951), pp. 6–8.
[328] *Ibid.*, p. 8, fig. 2.
[329] See Sanders (1967), p. 40, pl. 42.



Fig. 159 Large bowl fragment with remains of overall gilding, excavated from the Yung-Le strata at the imperial kiln at Ching-te-chen

True overall gilding, to give the illusion of golden vessels, was first tried in an experimental fashion at the Ching-te-chen imperial kiln as early as the Yung-Le reign period. An incomplete fragment of a large bowl was excavated there in +1994.

The unsatisfactory results apparent on this one sample make it clear that experimental overall gilding was a failure, and it was not for some 300 years, until the late Khang-Hsi reign period, that it was (successfully) revived. Then, it was applied to some rare Ching-te-chen imperial porcelains. The sumptuous quality of the gilded surfaces of those and later vessels seems more typical of cold than fired-on gilding, particularly as the ground beneath worn patches of gold can show a dull coral-hue rather similar to gold-size, and not a familiar colour in the Khang-Hsi overglaze-enamel repertoire.[330]

Chinese porcelains imported into Europe were frequently regilded, to give richer, thicker effects. These were achieved by mixing powdered gold metal with a low-temperature flux, often bismuth oxide, and firing that compound at *c.* 700°C to give a brownish colour. Burnishing made the soft metal spread into a continuous polished layer.[331]

[330] See Anon. (1989c), pp. 90–1, pls. 73–4; Li He (1996), p. 282, pl. 554, and p. 317. Red grounds are often used with gold leaf to enhance the warmth of its colour, as gold leaf is slightly green in transmitted light. This practice was understood in sculpture, when wooden images were gilded over a red lacquer bole to imitate gilt bronze. See Larson & Kerr (1985), fig. 5, Larson & Kerr (1991), p. 29.

[331] Kingery & Vandiver (1986a), p. 275.

SUMMARY OF PART 6: 'PIGMENTS, ENAMELS AND GILDING'

The slip-decorated wares of Neolithic China represented a style whose colourful painting did not survive the later Neolithic fashion for grey and black wares, and the development of ash-glazing in the Bronze Age. However, starting in the Warring States period in north China, experimentation with glass and glaze-bead technology encouraged the use of new synthetic pigments, notably Chinese Blue and Chinese Purple. Concurrently, the technology of lead glazes evolved until in the Han and Thang dynasties when scintillating high-lead glazes were used to embellish burial wares. Then in the late +12th century, traditional north Chinese lead glazes were modified to make low-firing red, green and yellow overglaze enamels for use on white-slipped Tzhu-chou style stonewares. Chinese overglaze enamels based on low-firing lead-rich glazes spread to south China in the +14th century, where they were applied to a few rare Ching-te-chen porcelains. After these initial experiments enamel production at Ching-te-chen was brought to a high level of accomplishment in the +15th century, with the making of fine enamelled porcelains for the imperial household. In the early +18th century a range of opaque and translucent enamels was introduced to Ching-te-chen to supplement and then, later, largely to displace, the traditional transparent enamels. These new translucent and opaque colours are known in the West as the *famille rose* palette, and in China as *fa-lang-tshai* 琺瑯彩, *yang-tshai* 洋彩, *fen-tshai* 粉彩 and *juan-tshai* 軟彩 enamels.

The oxides of the transition elements iron, copper and cobalt also served as both glaze colourants and as pigments for enamels. The history of cobalt-blue in China is especially complex, for at different times cobalt-bearing ores that were variously high in copper, iron, manganese, nickel and tin were utilised. It was the use of cobalt as an underglaze pigment on porcelain, to make 'blue-and-white', that represented China's most significant contribution to the use of the material in world ceramics.

The use of gold to embellish ceramics probably grew from the practices of gilding, inlaying and applying gold foil to metalwork. Later, fired gold ornament was applied to Ting ware in the Sung dynasty. 'High' overglaze-gold temperatures in excess of 800°C were slow to perfect, and after unsuccessful experiments at the beginning of the Ming dynasty, it was not until the +18th century that overall gilding was effected. Even so, Chinese gilding on porcelain appeared dim and lustre-less to Western eyes, so that exported pieces were often regilded upon their arrival in Europe.

PART 7: TRANSFER

CHINA'S TECHNOLOGY TRANSFER TO THE WORLD AND THE SIGNIFICANCE OF CHINESE CERAMICS IN THE CONTEXT OF WORLD CERAMIC TECHNOLOGY: 1

China's Influence on World Ceramics

China has been, without doubt, the single most important influence on the course of world ceramic history. This influence was conducted largely through the export from China of tough high-fired ceramics such as stoneware and porcelain, with the success of these high-temperature wares owing much to the outstanding qualities of Chinese raw materials, the effective organisation of China's ceramics workshops and factories, and the general efficiency of Chinese kilns. This was especially true in the south of the country, where most export wares were made. Penetration of world markets was achieved through internal management of trade, and by the maintenance of complex and extended networks overseas by Chinese and other agents. The marked superiority of Chinese bodies and glazes provided monopoly goods to trade, and spurred potters throughout the world to copy those wares with local resources.

But despite many attempts at imitation, Chinese wares remained the world's most advanced ceramic productions for centuries, as the desirability of Chinese ceramics as luxury products was paralleled by an initial inability on the part of other countries to imitate them. Korea was the earliest to succeed, producing white porcelain as early as the +9th century, and celadons that were admired in China by the +12th century. In Japan, stoneware traditions were advanced by the +8th century but it was not until *c.* +1620 that the first porcelain was made.[1] By the +15th century, ceramic technology in Vietnam and Thailand had developed to the point of challenging Chinese imports in Asian markets. Burma and Cambodia developed their own ceramic traditions, with design influence from both India and China. In all the afore-mentioned countries, however, Chinese ceramics continued to be imported alongside native manufactures.[2]

The lands of South and West Asia and Africa can be distinguished between those who saw no pressing need to develop further their localised pottery industries (Sri Lanka, India, Arabia, East Africa) and those who sought to imitate Chinese imported ceramics and to develop their own ceramic traditions (Persia, Iraq, Syria,

[1] Impey (1996), p. 84.

[2] Indonesia and the Philippines did not nurture domestic pottery industries before the +20th century, and Chinese ceramics remained important commodities there into modern times.

Egypt, Turkey). Of the latter, two points may be observed. The first is that (in common with countries in East and South-east Asia) copies were initially manufactured to help satisfy local demands, but later proved additionally valuable as export commodities. The second is that in imitating Chinese bodies and glazes potters were utilising local raw materials, and therefore often developed quite different technologies of manufacture from those of China.

In Europe, the technical primacy of Chinese wares remained unchallenged until as late as +1709, when true hard-paste porcelains began at last to be manufactured at Meissen in Saxony, using local kaolins fluxed with calcined alabaster.[3]

TECHNOLOGY TRANSFER

Given the scale and complexity of China's influence on the course of world ceramic history, both direct and indirect, it may be helpful to divide the transfer of Chinese ceramic technologies beyond China itself, into three broad themes. These can be classified as *Local, Remote* and *Reconstructive*, and summarised as follows:

- *Local technology-transfer* relied on the exploitation of geological resources similar to those that helped establish China's own ceramic industries. This was sometimes helped by the migration of Chinese potters who brought with them Chinese forms, making methods and kiln designs. Local transfer can be observed in Korea, Japan, Vietnam, Burma, Cambodia, Thailand and Laos, often using raw materials closely related to those used in Chinese workshops.
- *Remote transfer* was stimulated by trade in Chinese ceramics with countries far removed from China proper. They comprised lands in South and West Asia, southern and northern Europe, Scandinavia and Russia, and also North and South America. This was more a case of imitation by superficial reconstruction, a process that tended to create ceramics with compositions quite different from the Chinese originals, but often visually resembling them. Eyewitness accounts of Chinese ceramic manufacture were sometimes used in these researches, but not chemical analysis. In general such imitations of Chinese ceramics tended to be technologically inferior to the imported models, although, in a few examples, particularly European continental hard-paste porcelains and European red stonewares, the potters achieved technical qualities superior to the Chinese originals.
- *Transfer by reconstruction* uses scientific analysis followed by practical synthesis. Work of this type was carried out in Europe in the +19th to the +21st centuries by technologists such as Hermann Seger in Berlin, Georges Vogt at Sèvres, and Bernard Moore and J. W. Mellor in Stoke-on-Trent, in England. This type of transfer also embraces work by modern artist potters who have investigated the natures of Chinese clays and glazes from first principles, and then rebuilt them with available materials.

[3] Impey (1996), p. 2; Schulle & Ullrich (1982); Kingery (1986).

Strictly speaking it is only within the first and last categories that true technology transfer can be said to have occurred. Nonetheless, the second process was also important as it resulted in many of the major wares of world ceramic history. These wares represent the impact of imported Chinese ceramics on local potters and, besides the tin-glazed and stone-paste wares already mentioned, the process has inspired such fruitful misunderstandings of Chinese practice as English soapstone porcelains and English bone china. Both of these latter materials were originally devised as responses to Chinese porcelain in the +18th century, and bone china, which contains some 50% of burned animal bone, survives as England's main translucent white 'china' production.

UNDERSTANDING THE MATERIAL

It may seem an obvious point to make, but a proper understanding of how and when a technology has been transferred does depend to a large degree on a proper understanding of the materials and processes concerned. With many applied arts and technologies that spread from China, such as silk, printing and gunpowder, the natures of the processes or principles involved were unequivocal. In ceramics, however, the true characters of the original materials could be far from clear-cut and it is something of a paradox that the misunderstandings concerning the real natures of Chinese high-fired wares, evident in so much imitation of Chinese wares beyond China, have continued into modern times with some scientific investigations of the subject. The difficulty here has been that even the most thorough quantitative analyses cannot show the original mineralogies of the materials used to create the wares being studied, and this has made deductions concerning the true natures of the raw materials used by the Chinese potters far from straightforward.

This problem is particularly acute in the case of high-temperature wares, as these undergo the most profound changes in the kiln. Perhaps for this reason interpretations of Chinese ceramics based on chemical analysis have been dogged by serious errors from the late +18th century until well into the +20th century. For example, a proper understanding of a major early Chinese porcelain, *chhing-pai* 青白 ware, was not achieved in the West until +1982, and it was not until the same year that a good working knowledge of the differences between northern and southern Chinese white porcelains became finally established in the minds of Western scholars.[4]

As a result of these earlier mistakes, white Chinese porcelains and high-temperature glazes are still often referred to as 'feldspathic', while another erroneous idea, common in the Western literature, is the belief that the white clay-rich material

[4] The belief that Chinese *chhing-pai* wares were feldspathic porcelains (based on full microscopic and quantitative analysis) occurs in Sundius & Seger (1963), pp. 414–15 and 485. The first Western argument for the micaceous nature of *chhing-pai* ware was presented by Wood (1978), pp. 121–2, and expanded in Wood (1986), pp. 261–4. The +1986 paper is from the First International Conference on Ancient Chinese Pottery and Porcelain, held in +1982. It was at this meeting that the vital and consistent differences between northern and southern Chinese porcelains also first became obvious to Western researchers.

known as kaolin is an indispensable ingredient for the making of Chinese porcelains. In reality, as Parts 2 and 5 of this volume (*Clays* and *Glazes*) show, very few Chinese glazes are based on feldspar. Most Chinese porcelains are micaceous, with fine secondary micas acting both as aids to plasticity in making and as body-fluxes in firing, roles performed in Western porcelains by kaolinite and feldspars respectively. Also, we now realise that kaolin as a separate material tends to be an 'optional extra' in East Asian porcelain bodies, rather than the very basis of porcelain technology, as in the West. That such errors can occur, and then become so embedded in the literature, is a reflection of the fact that science is essentially concerned with measurement. Interpretations of just what these measurements might imply may be just as subjective and prone to errors as judgements made from ambiguous texts or confused archaeological strata.

In the event, what has proved vital for a proper understanding of Chinese ceramic technology has been access to full mineralogical analyses of raw materials local to the kiln sites being studied, while an equally important part of this process has been the establishment of some kind of overall geological context within which the kiln sites of China can be seen to have operated. It is perhaps this 'macro-geological' approach above all that has helped to bring order to the myriad data that have accumulated on Chinese ceramics, particularly over the last quarter of the +20th century.

North and South

As outlined at the beginning of Part 2, it now seems that the regional variations that are so obvious in the compositions of Chinese ceramics may reflect the original natures of the North China and South China blocks, with an imaginary divide separating their course of 'suture' and eventual fusion.[5] This line has a general east–west bias and runs through the Nan-shan mountain range 南山 in the west, through the Chhin-ling mountains 秦嶺山 and then eastwards north of the Huai river 淮河. Both mountain systems were raised when South China collided with North China, and this line of fusion separates China's major landmass into two roughly equal areas (see p. 51, fig. 8).[6]

Towards the eastern end of this division, in the more coastal zones of Chiangsu and Shantung provinces, the north–south divide takes a marked upturn, where the South China block has been displaced some hundreds of kilometres north-eastwards by the Than-chheng – Lu-chiang Wrench Fault System 郯城 – 廬江扭捩斷層系統.[7] This major feature runs some 3,600 kilometres from the north bank of the Yangtze river 長江 to north-eastern Russia. It is sometimes compared to North America's San Andreas Fault, though the 'Than-Lu' system is much

[5] Wood (2000b), pp. 15–24.
[6] Piper (1987); Ren Jiashun *et al.* (1987); Xu Guirong & Yang Weiping (1994).
[7] Xu Jiawei (1993), contains eighteen papers on the System.

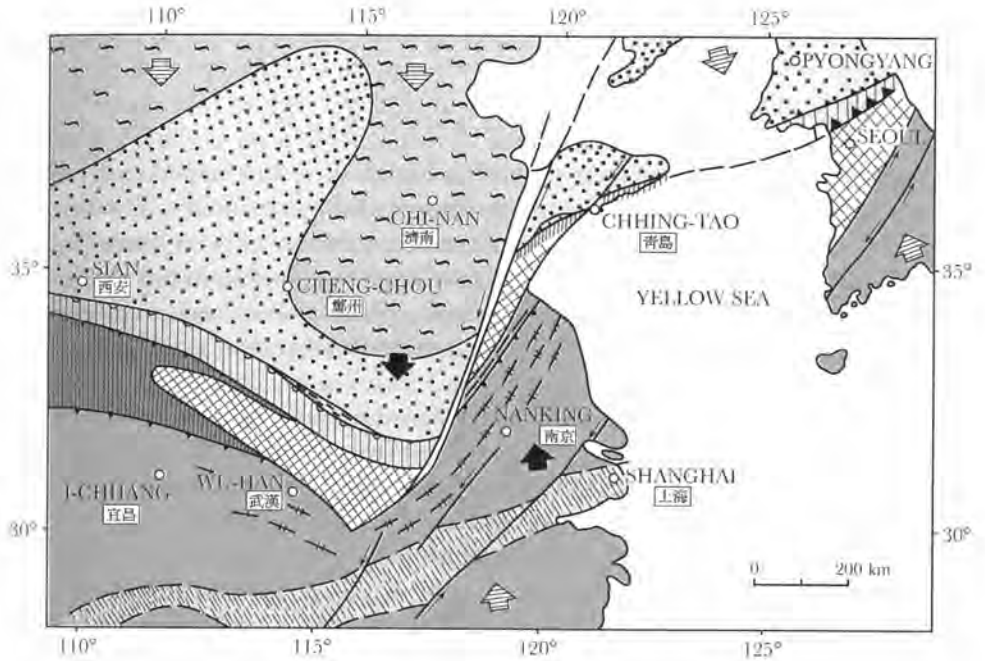


Fig. 160 Than-chheng – Lu-chiang Wrench Fault System

longer.[8] The north-eastwards displacement of this part of the south China block from the main southern landmass is some 700 kilometres in extent, and has resulted in a geology essentially similar to south China's appearing in South Korea (see Fig. 160). North Korea, however, seems a continuation of the north China block, with Korea's own north–south divide running more or less on the present DMZ. This tectonic phenomenon has had a profound influence on Korea's ceramic history. The exploitation of ceramic raw materials (essentially similar to those of south China) occurred in what is now west-coastal South Korea, but were often destined for consumption in the old capital of Pyŏngyang, in present-day North Korea.[9]

In the extreme south of China in Yunnan province, another ancient landmass called the Indo-China block (Indosinia) collided with the recently formed Chinese mainland. That event has helped to define the raw materials used in southern Yunnan, Vietnam, Thailand and Burma.[10] Raw materials in this region tend to be

[8] The abbreviation 'Than-Lu fault' refers to the counties of Than-chheng 郯城縣 in Shantung and Lu-chiang 廬江縣 in Anhui province, sited at either end of the Wrench System. The Than-Lu fault is 3,600 kilometres in length; the San Andreas fault some 1,100 kilometres long. See Xu Jiawei (1993), p. 52, table 3.1, for a full comparison.

[9] For discussions of Korean ceramic raw materials, see particularly Park Jong Hoon *et al.* (1973), and Koh Choo (1992).

[10] The timing of this latter collision is debated. See Yin Hongfu (1989), p. 329, for a discussion.

generally siliceous, like those of southern China, but the area seems to lack the purest porcelain stones with which south China is so abundantly blessed.

Export and Imitation

The availability (or non-availability) of raw materials therefore helped to determine the appearance of local products made to imitate Chinese ceramics. The first step in this process, however, was the export of Chinese ceramics to other lands. By tracing the various ways in which Chinese ceramics have been imitated beyond the country, much of China's influence on world ceramic history becomes clear, and the contributions that Chinese potters have made to world ceramic technology may be placed in a larger context.

Having acquired a taste for high-fired, glazed ceramics in the Chinese style, many lands developed their indigenous ceramic industries in order to satisfy local demand and to curb import costs. Chinese prototypes were adapted to local tastes and usages, with enterprising and appropriate design solutions as to form, surface and decoration.[11] Three factors were influential in creating new products. Firstly, the nature of local clays; secondly, the types of shapes, glazes and decorations that influenced design; and thirdly, the plan of kilns suitable for producing the wares.

Economic Benefits of Trade

The development of high-fired, glazed ceramics before the Han dynasty, and the manufacture of porcelain by +600, gave China great advantages in trade. Ceramics became valuable trade goods, alongside silk, gold, lacquer and other commodities.[12] Pottery and porcelain were exported from the Han dynasty onwards. Increased revenue was derived from countries in Asia, Africa and the Near and Middle East during the Thang period, where trade peaked in the Sung and Yuan dynasties. By the +14th century rare examples of Chinese ceramics had entered European collections, and from the +16th century, trading routes to China were established by European merchants.

In spite of potential fiscal advantage from the export of ceramics, the Chinese state controlled trade in a manner that was extremely restrictive at times. It has been conjectured that nomadic raids across her northern borders, and pirate raids along her coastline, contributed to rigorous insistence by the Chinese court on control of all forms of foreign trade and foreign relations. This regulation resulted in the state taking over many functions normally reserved for private

[11] Ho Chui-mei (1995) emphasises the dangers of seeing taste and technology transfer as being a one-way process from China to other regions. She notes the importance of Chinese communities overseas as customers for export ceramics, and stresses the role indigenous taste and technological expertise had in developing ceramic traditions outside China.

[12] See Chaudhuri (1985), map, pp. 186–7, where exports from China after +1,000 are calculated as: gold (5%), silk, raw silk, porcelain, lacquer (30%), tea, sugar, rhubarb, copper cash, spelter (65%).

merchants, and also manifested itself in the tribute system.[13] Restrictions on trade varied from period to period. In the Thang dynasty, for example, international commerce was relatively untrammelled, though certain valuable commodities such as spices had to pass through imperial customs posts. In the Sung dynasty (and particularly during the Southern Sung) trade was vital for the economy of south China.[14] The first half of the Yuan dynasty was characterised by tightened state control, which was relaxed in the early +14th century.[15] In the succeeding Ming dynasty, unofficial trade was illegal for much of the period. Such restrictive trade conditions, applied periodically by the Chinese state, were possible for three major reasons. Firstly, the Chinese internal market was so big and so strong that external sales were not continuously essential, and for certain periods of time the government could extract revenue from inland sources.[16] Secondly, a large volume of maritime traffic was carried illegally, with varying degrees of official connivance. Thirdly, the tribute system with foreign lands was not conducted for revenue purposes alone, though its commodities could be used as forms of payment within China.[17] Trade was adversely affected by the breakdown of state control, and civil war, at the end of the Ming dynasty and the beginning of the Chhing dynasty (*c.* +1620–1680). After that time and through the +18th and first half of +19th century, porcelain was exported in vast quantities to destinations from South-east Asia as far as North America.

Organisation of the Export Trade in China

Chinese ceramics were finding their way abroad as relatively unimportant components of a larger trade, from the Han period onwards.[18] It was not until the Thang dynasty, however, that a significant export market in ceramics developed. By the early +7th century a flourishing ship-building industry was turning out thousands of ocean-going junks.[19] Many of them were used to carry pots to countries of East and South-east Asia, from whence they were conveyed yet further afield. It is a curious fact that although Chinese ships were able technically to undertake long-distance voyages, merchants preferred to restrict direct travel to a relatively limited sphere. Chinese goods were transhipped and sold on to South-east Asian, Indian, Persian and Arab merchants,[20] who sold them at ports in South-east Asia, Sri Lanka, India,

[13] Chaudhuri (1985), p. 13.
[14] Kwan & Martin (1985a), pp. 49–50.
[15] Shih Ching-fei (2001), pp. 170–2.
[16] Cf. Ray Huang (1969), p. 103, Chaudhuri (1985), p. 15.
[17] Ray Huang (1969), pp. 103, 110.
[18] Ishizawa (1995) has compiled a detailed chronology of Chinese trade from the +1st to +5th centuries, based on Chinese texts. For Han and pre-Han trade, see Needham *et al.* (1971), pp. 442–8.
[19] *Hsin Thang Shu*, ch. 100, p. 3941, mentions that 500 large sea-going vessels were made at Hung-chou alone, during the period +627–649. Yeh Wen-Chheng & Lo Li-Hua (1991), p. 109. For a full exposition of the development of Chinese shipping, see Needham *et al.* (1971), pp. 379–486.
[20] Jewish merchants became important middlemen from the Sung period onwards.

Arabia and Africa.[21] In China coastal customs were established at Ming-chou 明州 (present-day Ning-po 寧波) and at Canton 廣州.[22] The major ports were these two cities and Yang-chou 揚州 (see p. 672). The premier Thang dynasty export wares were white porcelain from Hsing-chou 邢州 and Ting-chou 定州, northern green-splashed wares (a version of *san-tshai*), celadons (primarily Yüeh ware) from Chekiang province, ceramics from Kuangtung province and a variety of types from Chhang-sha 長沙 and other kilns in Hunan province.[23]

During the Sung and Yuan dynasties, markets for export ceramics thrived and ceramics were registered in official lists of imports and exports. Ceramics were conveyed from China both by land and by sea. *Sung Shih* (History of the Sung Dynasty, +1345) tells us that in +1084 an office was established at Lan-chou 蘭州, gateway to the overland Silk Route, to open up trading between China and 'the Barbarians'.[24] Maritime customs offices were established at Canton at the beginning of the Sung dynasty (+971), at Ming-chou in +989 and at Chhüan-chou 泉州 in +1087, while Hsia-men 廈門 was another important port.[25] During the Northern Sung period Canton was the most important south Chinese port, but after +1127 Chhüan-chou, which was nearer to the capital at Hang-chou 杭州, became its equal. By the Yuan dynasty Chhüan-chou had developed into China's chief coastal port, its population swelled by foreign traders, many of whom made their home in the city.[26] Private ship-building of huge ocean-going vessels of up to 600 tons is recorded at Chhüan-chou, Fu-chou 福州, Ming-chou, Chang-chou 漳州 and Canton, though not specifically at Hsia-men.[27] By the Southern Sung dynasty, after the northern half of the country had been overrun, the importance of those ports and of revenue derived from maritime trade increased.[28] The desperate need of the administration for specie, and the role of ceramics in commerce, are revealed in a record for +1219:[29]

> It is lamentable that officials often use gold and silver for trading abroad, thus losing valuable hard currency. Trading with silk textiles, porcelain, lacquer and other commodities is urged as an alternative.

China's Yuan dynasty Mongol rulers appreciated the benefits of overseas trade accumulated during the Sung dynasty, and developed policies to augment state commercial activity. In +1284 official capital was provided for ship-building, while aid was given for overseas sales under a profit-sharing scheme whereby 70% went to

[21] Lovell (1964), p. ix; Chaudhuri (1985), pp. 15, 50–1. Reports mention large-scale trading in ceramics by two named Arab traders, Sulayman (+851) and Ibn Khordádeben (+964), see Dillon (1976), p. 185.
[22] Yeh Wen-Chheng (1988), p. 128.
[23] Mikami (1990), writing about Chinese ceramics in South-east Asia, lists these types and also mentions black-glazed wares with white splashes from Honan province, found only in Indonesia.
[24] *Chung-Kuo Li-Tai Shih-Huo-Chih Cheng-Pien*, vol. 2, p. 462.
[25] *Ibid.*, p. 139. Clark (1991), p. 376, who also discusses the functions of the Office of Trade Superintendent (Maritime Trade Supervisorates *Shih-po Ssu* 市舶司) in the early Sung, pp. 377–8.
[26] See Anon. (1982b), Kwan & Martin (1985a), and Anon. (1985c).
[27] Kwan & Martin (1985a), pp. 49 and 52, quoting *Sung Hui Yao* and *Sung Shih*.
[28] Guy (1980), p. 19.
[29] *Chung-Kuo Li-Tai Shih-Huo-Chih Cheng-Pien*, vol. 2, pp. 466, 469.

government and 30% to private traders. From +1323 onwards merchants were unrestricted in their overseas voyages, though the Yuan government taxed them and reserved the right to send official trading vessels to sea.[30]

During the Ming period, officially sanctioned trade, and the passage of tribute ware, continued to grow. For example, in +1383 over 57,000 pieces of porcelain were sent as an imperial gift to Thailand, Java and other countries of South-east Asia, while further presentations were made in +1377.[31] Newly lucrative destinations included Okinawa 沖繩 (the Ryūkyū Islands 琉毬諸島), used as an entrepôt for an expanding Japanese market.[32]

As previously mentioned, however, for much of the dynasty non-governmental foreign trade was illegal. The first Ming emperor Hung-Wu enforced stringent prohibitions, and in +1370 Maritime Trade Supervisorates *Shih-po Ssu* 市舶司 were established in Ning-po, Chhüan-chou and Canton. These agencies, subordinate to the Ministry of Revenue, had as their functions the regulation of overseas commerce, the collection of customs duties, and the prevention of smuggling contraband goods.[33]

For a short time in the early +15th century, the Yung-Lo emperor attempted to monopolise tribute trade by sending out seven expeditions under the eunuch admiral Cheng Ho 鄭和 between +1405 and +1433. These expeditions had several purposes, that included the furtherance of tribute trade.[34] Ma Huan 馬歡, the Chinese Muslim geographer and interpreter on admiral Cheng Ho's staff, noted in his book *Ying Yai Sheng Lan* (The Overall Survey of the Ocean's Shores, +1451) the carriage of celadons to Ceylon and Champa (central Vietnam), and a burgeoning market in blue-and-white and other ceramics to Java, and Dhofar and Mecca in Arabia.[35] Another ship's officer, Fei Hsin 費信, described in his work *Hsing Chha Sheng Lan* (The Overall Survey of the Star Raft, +1436) how mainly blue-and-white porcelain was traded east to Taiwan and Okinawa, south to the Philippines, Timor, Thailand, Sumatra and Malaysia, and west to Sri Lanka, south-west India, Bengal,

[30] *Yuan Shih*, ch. 94 ('*Shih Huo Chih*'), pp. 25–6, ch. 205 ('*Lu Shih-Jung chüan*'), p. 11. Cf. Yü Chhang-Sen (1994), pp. 90–8, 106–16, and discussion in Chhen Chieh-Chin (1996).

[31] *Ming Shih*, ch. 324, pp. 3, 13, 16.

[32] Some Chinese ceramics of Sung-Yuan dynasty date have been found in the Ryūkyūs, but trade expanded when tributary relations were established in +1372. 69,500 pieces of ceramic were sold there in +1374, 19,000 pieces in +1385, and further unspecified quantities in +1376 and +1404. *Ming Shih*, ch. 323 ('*Liu-chhiu chüan*'), p. 1; Dillon (1976), p. 186. In +1404, a diplomatic official from the Ryūkyūs came himself to the Lung-chhüan area of Chekiang province, to make purchases of ceramics. *Ming Shih*, ch. 323 ('*Liu Chhiu chüan*'), p. 3; *Ming Thai-Tsung Shih Lu*, ch. 31, p. 1. The Ryūkyū Kingdom and its role as a trading base during the +14th to +16th centuries is discussed by Kurayoshi (1991). Shih Ching-fei (2001), p. 219, notes how different the finds on Okinawa were to those on the Japanese mainland.

[33] The Maritime Trade Supervisorates came to be dominated by palace eunuchs and caused great trouble with later Japanese and European traders. In +1474 the Chhüan-chou branch was moved to Fu-chou, and in +1522 all but the Canton agency were closed. Kerr (1982), p. 11; Hucker (1985), p. 429.

[34] The voyages are described at length in Needham *et al.* (1971), pp. 486–535. For a critique of Needham's interpretation of the historical reasons for the voyages, see Finlay (2000).

[35] *Ying Yai Sheng Lan* pp. 37a, 6b, 15a, 54b, 72b; Mills (1970), pp. 129, 85, 97, 153, 178; Needham *et al.* (1971), pp. 558–9.

the Maldive and Laccadine Islands, the Persian and Arabian Gulfs, and East Africa.[36]

However, Cheng Ho's voyages in no way mitigated the shortfall in trade ceramics caused by trade prohibitions, and the late +14th to mid +15th century seems to have been a time when external orders for porcelain were not satisfied.[37] In spite of this, private merchants managed to carry a considerable volume of ceramics abroad, both officially and unofficially. The scale of trade can be gauged from excavations in the docks on the canal at Yang-chou, in the vicinity of the Ming dynasty warehouses, that yielded 30,000 pieces of Hung-Wu to Hung-Chih period porcelain.[38] The shortages caused by Chinese trade prohibitions led to competitive ceramic production in the +15th to +17th centuries from Thailand and Vietnam.[39]

During the +16th century a huge illegal trade in ceramics continued, even after +1567 when a partial lifting of the sea ban led to international trade through the port of Hai-chheng 海澄 in Fukien province.[40] A study describing +16th-century trade, *Tung Hsi Yang Khao* (Studies on the Oceans East and West, +1618), noted how Chinese porcelain had enriched the lives of people in Borneo who formerly used leaves as food vessels. They also prized jars with dragon designs, in which they kept bodies of the deceased instead of burying them.[41]

Evidence furnished from many sites indicates that export trade in ceramics continued through the Ming period and into the Chhing. The collapse of the ceramic industry in China during the troubled period of transition from the Ming to Chhing dynasties led to competition from Japan in the +17th century.[42] China continued to sell her pottery and porcelain abroad, however, finding new markets with expatriate Chinese communities of South-east Asia in the +19th and +20th centuries.

[36] Mills & Ptak (1996), pp. 90, 97, 87, 44, 52, 55, 60, 64, 67, 69, 77, 103, 71, 99, 100, 105, 102, 104.

[37] For a discussion of the so-called 'Ming gap' see Brown (1997).

[38] Pers. comm. from Chhien Wei-Pheng 錢偉鵬, involved in excavations there.

[39] To represent many sites in South-east Asia, see Pulau Tioman, Kwan & Martin (1985b), p. 78; and Banten Girang, Dupoizat (1992), p. 57. A more complete overview of sites in South-east Asia, with maps, is provided by Guy (1987).

[40] Ray Huang (1969), p. 99; Ho Chui-Mei (1994a), p. 66, note 6.

[41] *Tung Hsi Yang Khao*, ch. 4, p. 18. Cf. Hirth (1888), pp. 51–5, who suggests that this custom was transported along with porcelain by traders from Fukien province, where porcelain jars were also used to preserve relics of the dead.

[42] Earle (1986), pp. 74–82; Ho Chui-Mei (1994a).

LOCAL TECHNOLOGY-TRANSFER: THE INFLUENCE OF CHINESE CERAMICS IN EAST AND SOUTH-EAST ASIA

KOREA

Earliest to develop wares influenced by Chinese models were Korea and Japan. Chinese merchants were recorded as being frequent visitors in Korean ports.[43] During the Northern Sung dynasty Korean ceramics were prized imports, as the admiring comments of +1123 by the Chinese envoy to Korea show (see p. 537). In south Korea an essential continuity of geology with south China made production of ash-glazed stonewares of the Chinese type straightforward. Small climbing kilns were in use in Korea from at least the +3rd century, probably introduced from China following the invasion and occupation of the country.[44] These kilns were first used in Korea to fire beaten and stamped unglazed grey earthenwares. True unglazed stoneware seems to have evolved in a long period leading up to the +6th century,[45] while in the early +9th century greenish ash-glazed stonewares of the Chinese type began to be made from essentially similar clays, but more than two millennia later than in China.[46] However, a very Korean improvement to the principles of the south Chinese greenware tradition occurred when southern Korean potters substituted porcelain stone for body-clay in their celadon glaze recipes in the early +11th century.[47] This low-titania material gave the celebrated blue-green glazes of Koryŏ dynasty celadon-wares that were so admired by Hsü Ching 徐兢. Another major Korean ceramic technique was the use of white and black ceramic inlay in the grey stoneware bodies, a process that became well established in the +12th century.[48] The inlay technique allowed sharp contrasting detail to be used under fluid calcareous glazes. Dragon kilns with side holes for stoking were standard by the Koryŏ period, for the manufacture of celadon-glazed stonewares.[49] Excavations show that kilns of the second half of the +10th to the +12th centuries were single-chambered, tunnel-shaped structures of 10–30 metres length, that sloped at an angle of 12 to 15°.

As for white porcelain production using quartz-mica rocks, it now seems that Korean potters may well have anticipated China in this important advance in porcelain technology as some white Korean porcelains of the early +9th century have

[43] Clark (1991), p. 381.
[44] Barnes (1993), p. 217.
[45] Tite *et al.* (1992), pp. 64–9.
[46] Koh Choo *et al.* (1999), p. 53 and pp. 56–9, tables 1 and 2.
[47] Wood (1994), pp. 52–3.
[48] Contrasting inlay on Korean ceramics had been employed in a minor way as early as the +10th century, but was first developed properly in the mid +12th. Hughes *et al.* (1999), p. 287.
[49] Wood (1994), pp. 52–6, 58–61.

recently been found at the southern kiln site of Pangsan-dong.[50] Although this does not signify Korea as the maker of the world's first porcelains,[51] it does seem to place Korea as the pioneer maker of porcelains of the quartz-mica type. These became the standard materials exploited across southern China, south Korea, and also at the great Japanese porcelain centres in Kyūshū near Arita.[52] White porcelains continued to be manufactured during the Koryŏ period (+11th century), with mineralogies comparable to those of wares from the Ching-te-chen region of Chiangsi province.[53]

Further evidence that Korean potters were significant innovators in their own right can be seen in the substantial use of kaolin in the bodies of plain white glazed porcelains made at the south western site of Ch'ungyodong in the 15th century.[54] The intractable nature of some Korean porcelain materials, however, led to the failure of vessels. Many pieces that passed inspection, and are preserved in collections today, are warped and sometimes cracked to a marked degree. As in China, the Korean court maintained its own central kilns, which were in Kwangju (north east of Seoul) after +1466. They were of stepped, chambered climbing type (see pp. 360–4), and by the +17th century fine white clays were being carried there from some distance. Unlike in China, in the second half of the +18th century it is recorded that official kilns in Kwangju district were moved every ten years to be near fresh supplies of good timber.[55]

In other ways Korea was less advanced than China: even the finest Korean celadon and white porcelain glazes remained generally fluxed with wood ash, and China's use of limestone as a glaze-flux does not seem to have been transferred to Korean workshops. However, it should also be said that the artistic quality of Korean high-fired ceramics is quite exceptional. In this respect (as with many other ceramic traditions of East Asia) China has been an obvious influence, but the Chinese ceramic styles and technologies have been renewed, reworked and often transcended by the personal visions of their inheritors.

JAPAN

Japan followed China in the manufacture of high-temperature ceramics in the +5th century, some 2,000 years later than on the mainland.[56] Japanese stonewares were fired in single-chambered tunnel kilns from the late +5th century.[57] These were

[50] Koh Kyong-sin (2001).

[51] The world's first porcelains were produced in north China, from very high-fired sedimentary kaolins in the late +6th to early +7th centuries, see pp. 146–55.

[52] Yoshida Najiro & Fukunaga Jiro (1962).

[53] N. Wood, text written for catalogue for the Fitzwilliam Museum, Cambridge (2004, in press). See also Koh Kyong-sin (2001).

[54] Koh Choo *et al.* (2002).

[55] Yun Yŏng-I, text written for catalogue for the Fitzwilliam Museum, Cambridge (2003, in press). See also Gompertz (1968), pp. 16–22, 45–7, 54–63.

[56] Harris (1997), pp. 80–1.

[57] Faulkner & Impey (1981), pp. 16–17.

simple kilns, made by digging a tunnel in the hillside or by roofing a deep trench. The design was probably imported from Korea rather than China, although its ultimate origins would have been Chinese. Sue wares 須恵器, made in many parts of the country, were bearing ash-glazes by the mid +8th century. More specialised Shirashi wares 白瓷窯 from the Tōkai 東海 district of central Honshū 本州 were produced in imitation of imported Chinese ceramics, in particular Yüeh wares 越窯.

Excavations and handed-down pieces reveal the high value placed on imported Chinese wares, with black teawares of the Chien type from Fukien province becoming especially popular.[58] These were copied from the +12th century, while sites such as Seto 瀬戸 in central Honshu also developed traditional Japanese ash-glazed stonewares into rustic copies of Chinese *chhing-pai* 青白 wares and Yüeh-type wares. These local imitations were widely available in areas where people appreciated Chinese export wares but found them either unavailable or too expensive to buy.[59] The unrefined aesthetic of local wares soon came to rival, and even to surpass, the appeal of the mass-produced imports.

The scale and nature of the export trade from China to Japan can be calculated from a single find, the so-called 'Sinan shipwreck' (its name deriving from a Korean site on the coast). A laden ship left Ning-po 寧波 on the eastern Chinese seaboard in the summer of +1323, carrying a cargo of ceramics bound for Japan. Less than a month later it was wrecked off the south-east coast of Korea. Careful excavation by Korean archaeologists yielded more than 6,000 items of ceramic, many of them intact. They came from kilns at Lung-chhüan 龍泉 in Chekiang province, Ching-te-chen 景德鎮 and Chi-chou 冀州 in Chiangsi, with a small percentage of northern wares and many from Fukien and Kuangtung provinces.[60] The average quality of wares was higher than that destined for most of South-east Asia, indicating the discerning nature of the lucrative Japanese market.

Significantly, not a single piece of blue-and-white was recovered from the Sinan shipwreck, corroborating a start date of manufacture at Ching-te-chen as being *c.* +1330. White and decorated porcelain constituted a valuable export from China to Japan from the later +14th century onwards. Manufacture of a substitute, local material eluded Japanese potters until the early +17th century, when local potters on the far southern island of Kyūshū 九州 identified porcelain quartz-mica porcelain stones at Izumiyama 泉山.[61] The porcelain stone was used unmixed, and seems to have had low plasticity and relatively low shrinkage.[62] This area is on the extreme fringe of the geological system that includes south China and Korea, and Japanese porcelains can be regarded as part of this same technical tradition. Similar

[58] See Anon. (1994c) and Anon. (1994d).
[59] Earle (1986), p. 32.
[60] The ship and its contents are described in Munhwa Kongbu Munhwajae Kwalliguk (1985).
[61] Yoshida Naojiro & Fukunga Jiro (1961), pp. 36–41; Impey (1996), pp. 33–4.
[62] Impey (1996), pp. 33–6.

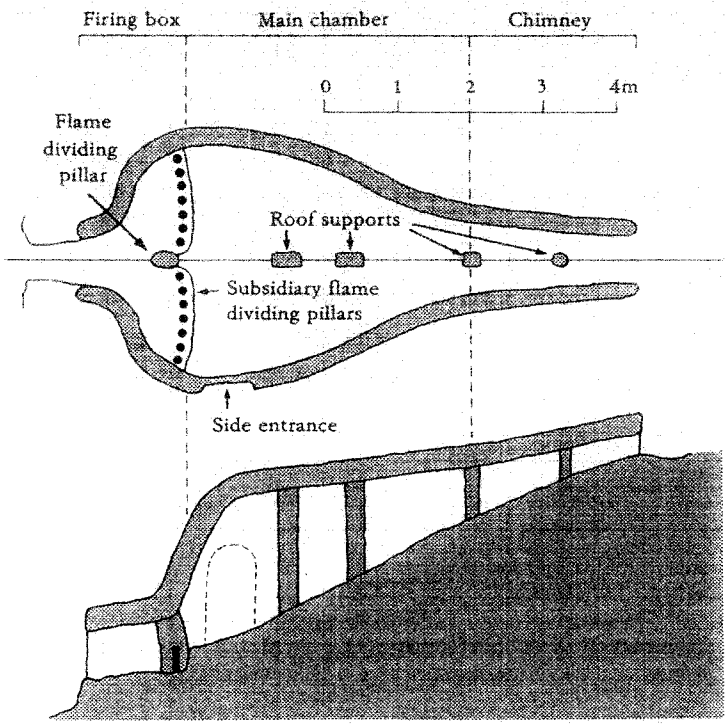


Fig. 161 Japanese *ōgama* kiln

quartz-mica volcanic rocks were also exploited near Arita at this time to make close copies of Chinese Lung-chhüan cleadon-wares. A superior porcelain stone from the nearby Amukasa island 天草諸島 was found and used for the finest white porcelains towards the end of the +17th century. As with Korea, Japanese porcelain glazes were essentially mixtures of porcelain stone with wood ash, rather than porcelain stone and limestone in the Chinese manner.

Around +1500, a superior type of kiln rather similar to the early Ming 'horse-shoe-shaped' kiln at Ching-te-chen developed. This Japanese *ōgama* kiln 大窯 was set into the hillside, with domed roof supported by pillars and improved firing-box with flame-dividing pillars, and it permitted more even and efficient firing.

During the +16th century, climbing kilns with rudimentary chambers whose dividing walls had pierced holes at the base, came into use at Karatsu 唐津 in northern Kyūshū, their technology most likely transmitted by immigrant Korean potters. Japanese porcelains at Arita 有田 were fired in divided-chamber kilns of the 'developed' dragon type. That model was not unlike the 'chicken cage' and later

'step kilns' pioneered in Fukien province in the late +13th century, and then developed and refined through to modern times (see pp. 360–4). By the first half of the +17th century its domed, ascending chambers could number up to 26, forming kilns of up to 62 metres in length at that date.[63]

The specific technical influence here, in terms of quartz-mica porcelain stones and ash-rich porcelain glazes, should perhaps be regarded as Korean, while techniques such as painting with underglaze cobalt-blue and, by the mid +17th century, with coloured overglaze enamels, were essentially Chinese.[64] The early and highly effective use of the overglaze-blue enamel in Japanese porcelain distinguishes the Japanese overglaze enamel tradition from Ching-te-chen's at this time. This fine overglaze-blue seems to have depended on the importation to Japan of a Persian cobalt of particular purity.[65]

Such a brief survey, of course, concentrates on the parallels between Chinese and Japanese ceramics rather than on their differences. For their own part Japanese potters made much greater use of feldspathic glazes[66] (scarcely known in China) and imbued their wares with a sophisticated, poetic and asymmetrical sense of design and detail quite different from the 'squarer' spirit of the ceramics made on the Chinese mainland.

Chinese Ceramics in South-East Asia

Chao Ju-Kua's 趙汝适 monograph *Chu Fan Chih* (Records of Foreign Nations, +1225) mentioned trade to the Chinese outpost of Hai-nan 海南島 (Hai-nan island) and to Korea (*Hsin-lo* 新羅), noting that the latter produced its own ceramics. This notable record of China's contacts with the outside world listed other lands that received ceramics:[67]

- *Chan-chheng* 占城 (a kingdom along the coast of central and northern Vietnam)
- *Chen-la* 真臘 (Cambodia)
- *San-fo-chhi* 三佛齊 (Srivijaya, Sumatra)
- *Tan-ma-ling* 單馬令, *Ling-ya-ssu-chia* 凌牙斯加, *Fo-lo-an* 佛羅安 (all on the Malay

[63] *Ibid.*, pp. 23–4, 33–4, 40–1. The whole chapter on 'Materials and Techniques' in this book is informative. Kiln furniture, saggers and muffle kilns are also discussed.

[64] Volker (1954), p. 27, gives detailed Dutch records of 'porcelain paint' imported from Amoy [Hsia-men] to Japan from +1654 to +1682. Tradition associates the beginnings of overglaze enamelling on Japanese porcelain with information from a 'Chinese official' in Nagasaki 長崎 in +1647. See Jenyns (1965), pp. 109–17, for a full discussion.

[65] Also mentioned in the +17th-century Dutch Registers as 'red Arabian earth' or 'red Persian earth' and probably the cobalt arsenate mineral erythrite. The date of +1658 is sometimes given for the first use of the Japanese overglaze-blue porcelain enamel. See Sir Harry Garner's letter cited in Jenyns (1965), p. 124.

[66] Faulkner & Impey (1981), p. 2, credit the Mino 美濃 potters of the Momoyama period 桃山時代 (+1573–1615) with the introduction of the feldspathic glaze in Japan, largely for the improvement of underglaze-iron painting: 'By decreasing the proportion of ash in the glaze, the Mino potters were able to remedy this fault [i.e. blurred painting] and in so doing gave rise to the almost purely feldspathic glaze.' See also Vandiver (1992), pp. 224–5, table 1, for analyses of late +16th-century Mino ware feldspathic glazes.

[67] *Chu Fan Chih*, pp. 3a, 4b, 7a, 8b, 10b, 12b, 15a, 24b, 34b, 35a, 36a, 57a, 39a; Hirth & Rockhill (1911), pp. 49, 53, 61, 67, 73, 78, 88, 126, 156, 158, 160, 177, 168. Chao Ju-Kua was a superintendent of the Fukien province *Shih-po Ssu* 市舶司. See Shih Ching-fei (2001), p. 165, and pp. 716–17 of this volume.

Peninsula), where porcelain consignments included bowls, basins and similar, common, heavy articles
- *Lan-wu-li* 藍無里, *Hsi-lan* 細蘭 (Ceylon)
- *She-pho* 闍婆 (Java), with specific mention made of celadons and white porcelain
- *Nan-phi* 南毗 (Malabar coast), that sent products on to ports nearer China, where they were traded for porcelain
- *Tsheng-pa* 層拔 (Zanzibar)
- *Po-ni* 渤尼 (Borneo), with specific mention made of celadons and white porcelain
- *Ma-i* 麻逸 (Philippines).

This Sung dynasty text described export ceramics in the same categories as those found on the Sinan shipwreck, namely a majority of celadons and white porcelain. By +1349 the Yuan dynasty writer Wang Ta-Yüan 汪大淵 described a wider range of export wares, comprising celadons from Lung-chhüan, white porcelain, *chhing-pai* porcelain from Chhu-chou 處州 (in Chekiang province) and *chhing-pai hua-tzhu* 青白華瓷 (i.e. blue-and-white). Wang's book, *Tao I Chih Lüeh* (An Outline History of Island-Dwelling Peoples, +1349), recorded observations from two ocean voyages of +1330 and +1337–9 through South-east Asia and the Indian Ocean as far as eastern Africa. He listed 99 separate countries, over half of which imported Chinese ceramics.[68]

Over the last twenty years archaeological activity across South-east Asia, from the Philippines to southern Indonesia, has confirmed the importance to the export trade of Chinese kilns from the three southern provinces of Chekiang, Fukien and Kuangtung. Chekiang province had supplied both internal and external markets since the Han period, while export products from Fukien and Kuangtung provinces increased during the Sung and Yuan dynasties. Peter Y.K. Lam's research on kilns in Kuangtung province shows that a major period of export during the Northern Sung dynasty coincided with Canton's florescence as a maritime port (see p. 716).[69] From the +13th century, when Chhüan-chou emerged as the dominant harbour, kilns in Fukien province became more prominent. The Southern Sung and Yuan kilns of Fukien produced vast numbers of ordinary-quality wares. These mass-produced ceramics have not been found in huge numbers in Chinese contexts, for they were produced for the world market. Rough celadons, *chhing-pai* wares and more refined black teawares were manufactured in their millions, at thousands of small kilns. The bulk of the export trade was in celadons, and for an idea of their scale of manufacture, one should note that archaeologists have excavated more than 140 kilns of Sung-Yuan period date in the Chhüan-chou region alone.[70]

[68] Beamish (1995), discusses the export of blue-and-white using *Tao I Chih Lüeh* as a major source.
[69] Peter Y. K. Lam (1985), pp. 1, 9.
[70] Thang Wen-Chi (1995), pp. 258–9.

In the Ming and Chhing dynasties, celadons from Chekiang province and sturdy storage vessels from Fukien and Kuangtung provinces bulked the export trade. By far the largest supplier, however, was Ching-te-chen. Blue-and-white was shipped abroad in vast quantities, supplemented by a small proportion of the more expensive overglaze-enamelled wares. Knowledge of export cargoes has been enhanced by a steady programme of archaeology at mainland sites in South-east Asia, supplemented by a growth in the perilous but profitable recovery of shipwreck cargoes.[71]

VIETNAM

In South-east Asia, Vietnam was the country associated most closely with China. The northern part of the country had been (in Chinese eyes) a colony for most of the period from −111 to +939. During the Han period, sinicised elements of Vietnamese society adopted Chinese customs of burial and manufactured appropriate ceramics from local, fine-textured pale-firing clays. The Red river basin and delta contained good deposits of stoneware clay. Numerous Chinese ceramic forms and making techniques were borrowed and developed, including the tendency to use thin patchy glazes enhanced with thicker glaze-splashes. The bodies of some Vietnamese wares of the +1st to +3rd centuries can be surprisingly white, but their high-titania levels and low-alkali contents disqualify them as porcelains (or precursors of porcelain) in the strictest sense. These ceramics were relatively high-fired in cross-draft kilns similar to contemporary Chinese models.[72] The technological relationship of Vietnamese with Chinese ceramics is still an under-researched area, but recent work suggests that there may be some connection with glass from south India as a glaze material in both traditions at this time (see pp. 466–8). India, in fact, rather than China, was the major cultural influence in South-east Asian culture during the +1st millennium, when both Indian and local forms dominated in the area.

Little evidence has been gathered to date about ceramic production in the second half of the +1st millennium, though by the +9th century local earthenwares in styles common to those of south China were produced.[73] After +1009, distinctive glazed ceramics were produced in the Hanoi area, including white stonewares with petal motifs based on Northern Sung wares.[74] With the arrival of Chinese export ceramics in the +11th to +12th centuries, local copies of wares from Chekiang, Fukien and Kuangtung provinces in south China become abundant. Chinese settlers followed the export trade to South-east Asian ports, and Chinese potters may have been among these immigrants. Limitations set by the qualities of local raw materials

[71] A provisional list of wrecks significant to the history of Chinese ceramics, and dating between +1500 and +1752, is published by Carswell (2000), p. 183. For a detailed review of the contents of a Philippines shipwreck, with typical inter-Asian trade ceramics, see Goddio, Pierson & Crick (2000).

[72] Morimoto (1997), p. 85, fig. 1.

[73] Guy (1989), pp. 42–4; Guy (1997), p. 12.

[74] *Ibid.*, pp. 46–7 and pp. 18–19. Northern Vietnam was probably producing wares imitating Chinese types during the Thang dynasty occupation of territory there. However, archaeological excavation and analysis is as yet incomplete.

seem to have been a permanent difficulty in this region, but later Vietnamese ceramics copied and developed the forms and ornament of Chinese blue-and-white porcelain in the +15th to +16th centuries to a particularly high level of achievement.

Underglaze-iron decorated stonewares were made for export from the +13th century, but it was the Ming invasion and occupation of +1407–28 that stimulated production of blue-and-white.[75] While showing strong superficial similarities to +14th-century Chinese blue-and-white wares, the body-materials used for +14th- to +16th-century Vietnamese blue-and-white tend to be greyer and non-translucent. Nonetheless such wares were often magnificent in spirit and made effective substitutes for Chinese blue-and-white when exports of Chinese porcelains were restricted during the Hung-Wu and Hsüan-Te reign periods. We do not know at present whether the cobalt pigment used in Vietnam was a manganese-cobalt ore (as used in Yunnan), or of the type of iron-cobalt material then used at Ching-te-chen for finer wares. It is tempting to see the separate geological history of the Indo-China block as being a limiting factor in the technical qualities of South-east Asian ceramics, which hardly ever include white translucent porcelains, although more data are needed to test the idea.

Limited archaeological investigation has revealed kiln sites at Chu Lao, Ngoi, Hop Le and My Xa, on the Red river near Hanoi and in the delta area.[76] An indication of the high calibre and large output of those kilns during the +15th to +16th centuries was provided by a single, salient shipwreck. From +1995 to +1997, finds totalling over 150,000 complete ceramic items were recovered from a sunken vessel off the coast of central Vietnam. It has been estimated that the original cargo could have exceeded a quarter of a million pieces, the vast majority comprising top-quality Vietnamese blue-and-white, with a significant proportion of enamelled-and-gilt and monochrome Vietnamese wares.[77] This find demonstrates the extent to which Vietnamese wares were able to compete with Chinese, in export markets of the +15th to +17th centuries.

Two types of kiln developed at the Red river sites, a shorter type called *lò cóc* (frog kiln) and a longer type called *lò rông* (dragon kiln). The latter was sometimes quite short and although related to Chinese dragon kilns was not identical to them. Later came the *lò dàn* or chambered kiln. All were wood-firing.[78] Excavation of +18th- and +19th-century kilns in the Hanoi area revealed small dragon kilns with separate fireboxes, and larger, multi-chambered climbing kilns. Both types were used to fire blue-and-white porcelain.[79]

[75] Brown (1988), pp. 23–9. Stevenson (1997), p. 38 disputes the simplicity of this explanation, arguing that Ming prohibitions against private trading, particularly those of +1436–65, left markets open to exploitation by the Vietnamese.

[76] Guy (1989), p. 48; Guy (2000), p. 128.

[77] The finds are described and illustrated in Guy (2000), who also provides a description and illustration of the type of vessel used.

[78] Morimoto (1997), pp. 89–90.

[79] Tran Khanh Chuong (1987), pp. 100–5, described a dragon kiln in Ha Bac province 3.5 metres long, a ten-chambered kiln at Bat Trang (Hanoi) that was 12 metres long, 2.6 metres high and 4 metres wide, and another six-chambered kiln at Bat Trang. He estimated that the latter kiln had a total firing cycle of eight days, using both coal and wood as fuel.

THAILAND AND CAMBODIA

In Thailand, archaeology has had more opportunity to develop, and has traced the evolution of kilns in the northern central region, particularly in the area of Sisatchanalai. From around the +10th century, simple, subterranean, cross-draft kilns dug into river banks or sloping ground were used.[80] Later, in the +15th and +16th centuries, celadons and underglaze iron decorated wares were made at Sisatchanalai for export, and those wares competed successfully overseas. Thai export wares were stoneware rather than porcelain as Thailand did not share the geology of south China with its copious deposits of porcelain stone. Nevertheless, Thai export wares were high-fired. Some kilns actually melted on the inside and produced up to 50 centimetres of slag, indicating both high temperatures and prolonged usage.[81] At both Sisatchanalai and nearby Sukothai, the main kiln type from the late +14th century onwards was an above-ground, cross-draft, beehive-shaped model built of pre-fired bricks. It had a tapering domed profile with recessed firing-box, a single ascending firing chamber and a tall round chimney at the back.[82] Geographical position, geology and history preclude much direct influence from China in the development of ceramic technology, other than a desire to imitate some elements of imported products. Nevertheless, it is interesting to note the appearance of domed, cross-draft kilns.

During the great Angkorian period of Cambodian history (+10th to +15th centuries) ceramic traditions developed. Indian styles were reflected in earthenwares, while from the +10th century technology and skills were probably borrowed from China. Chinese influence was short-lived, for by the mid +11th century it seems that Khmer potters continued in indigenous traditions that derived inspiration from India.[83] A range of ceramic types in the stoneware range were produced, some bearing pale-green glaze and some deep-brown. Glazes had a tendency to fine crazing and did not always adhere well to the body. Huge numbers of architectural ceramics were made in addition to vessels. As the Khmer state declined, so also did Khmer glazed ceramic production, while from the +12th century imported Chinese wares increased. Full-scale excavation of kilns within Cambodia have not yet been completed, so information on Khmer kilns is derived from sites in north-east Thailand. There, excavation of more than 80 kilns revealed clay slab-wall cross-draft kilns whose typical size was 15 metres in length and 1.5 metres in width, having clay supporting columns along the length.[84] Kiln technology was adapted to suit local conditions and requirements, and no direct influence from China may be inferred.

[80] Hein (1990), p. 205.
[81] *Ibid.*, p. 215.
[82] Guy (1989), pp. 27–32, pl. 11; Hein (1990), pp. 209–17.
[83] Brown (1988), p. 42; Guy (1998).
[84] Guy (1998).

REMOTE TRANSFER: THE INFLUENCE OF CHINESE CERAMICS IN SOUTH AND WEST ASIA, AND AFRICA

Chinese Ceramics in South and West Asia

It was the 'Maritime Silk Route' that transported the bulk of ceramics westwards, by reason of their weight and fragility. Ships running down the coast of Indo-China either sent their goods across the Malay Peninsula at the Isthmus of Kra, or passed through the straits of Malacca into the Indian Ocean. Then trading vessels crossed the Bay of Bengal to Sri Lanka and India. From the western coast of India they sailed onwards to destinations in the Persian Gulf, the Red Sea and the eastern coast of Africa. A small proportion of goods were carried overland through Central Asia, the route branching in several places to allow passage south to India and north to Kazakhstan, before splintering south of the Caspian Sea to penetrate major commercial centres of West Asia. Chinese ceramics were traded to all those destinations, and sherds have been excavated at a plethora of sites. Here we will sketch in a few of them, and consider the evidence that they provide.

Sri Lanka (Ceylon) is repository to a great variety of sherds of all dates from the Thang dynasty through to the +20th century. The site of Mantai in the north-west, Ceylon's premier port until *c.* +1,000 and one of the most important trading posts on the east–west maritime route, has yielded quantities of Chinese, local and Islamic wares. Persian traders with China established a factory there as early as the +5th century, though Chinese sherds found in the area date no earlier than the +8th century. They comprise painted stoneware from Chhang-sha 長沙, whitewares, Yüeh wares 越窯 and wares from Kuangtung province, all of +8th- to +10th-century dates. Other sites, such as Allaippidy in the north, were more time-specific. There, a vessel of Northern Sung date had been wrecked *c.* +1100, leaving an assemblage of export wares from kilns in Chekiang, Fukien and Kuangtung provinces.[85]

China and India traded with one another from the –2nd century, and Indian merchants, especially those from the southern states, were active in commerce.[86] Limited excavation on the sub-continent has revealed +9th- to +10th-century whitewares, celadons and painted Chhang-sha wares, and individual examples of Sung export wares. However, ceramics seem to have played a relatively minor role in trade before the +14th century, when the Mongol empire exerted control in both lands. It

[85] Carswell (1985a), pp. 116–18; Carswell (1985b), pp. 30–47.
[86] See Ray (1995).

was not until the +16th century under the Muslim Mughal emperors, when Europeans started to gain trade supremacy in Asian waters, that special orders of Chinese ceramics made to Indian taste became commonplace.[87] At no time did India attempt to mimic Chinese export wares, and indeed pottery was not a craft that developed to great technical heights, unlike the sophisticated textile, metalworking and lapidary industries. This was probably caused by religious constraints, for although Muslims used porcelain, the majority Hindu population eschewed ceramics.[88]

Trade to Western Asia was carried by Persian and Arab traders from the +5th century, and they were later joined by Jewish merchants. Before *c.* +1,000 the journey to China was undertaken by traders in one passage from their home ports, while after that date the voyage was broken down into two or three stages and products traded through entrepôts along the maritime route.[89] The first regular imports of Chinese ceramics to the Near East occurred in the very late +8th century, and developed strongly there during the +9th and +10th centuries, a trade epitomised by Samarra, near Baghdad, a city that prospered in the +9th and +10th centuries. Its citizens spent part of their wealth on imported luxuries like Chinese ceramics that were transported up the river Tigris from the ports of Basra and Siraf on the Persian Gulf. As Al-Mansur is reported to have remarked when the foundations of Baghdad were laid in +762:[90]

> We have the Tigris to put us in touch with lands as far as China, and bring us all the seas yield as well as the foods of Mesopotamia and Armenia.

Luxury goods from the West were greatly desired in China. Chao Ju-Kua (+1225) listed some covetable items exported by 'Arabs' (*Ta-shih* 大食): top-quality pearls, ivory, rhinoceros horn, frankincense, ambergris, putchuk, cloves, nutmegs, benzoin, aloes, myrrh, dragon's blood resin, asafoetida, borax, opaque and transparent glass, shell, coral, cat's eye stone, gardenias, rose-water, nut galls, yellow wax, soft gold brocade, camel's hair cloth, *tula* (cotton tree) cloth and satin.[91] More ordinary items were carried as ballast: dates, sugar, building materials, timber. On the return journey from China, ceramics were a principal ballast.[92] The remains of those ceramics have been found in many places.[93] Recent archaeological excavations and surveys have recorded the presence of Chinese

[87] The evidence is summarised by Greensted & Hardie (1982).

[88] Hindu notions of religious pollution meant that earthenwares, which were porous and could not be scrupulously cleansed, had to be discarded after use. The injunction was extended to porcelain, making it too expensive to use. Devout Hindus refused to employ any ceramic utensils, substituting leaves as plates and metal vessels. Finlay (1998), p. 158.

[89] Chaudhuri (1985), p. 50, maps 8 and 9.

[90] Needham & Wang (1954), p. 216, note d, citing Hitti (1949), p. 393.

[91] *Chu Fan Chih*, ch. 1, p. 22b; Hirth & Rockhill (1911), p. 116.

[92] Chaudhuri (1985), p. 53.

[93] For a survey of sites and literature see Insoll (1999), p. 155.

material at sites on the Gulf, and in Yemen on the Red Sea and Indian Ocean coasts.[94]

Next, we shall consider an accumulation of wares that mark the furthest point west in Asia reached by Chinese trade ceramics. Their geographical location, and their dates of acquisition, also mark an important junction for trade into Europe. The assemblage is that of the Ottoman Sultans at the Topkapi Palace in Istanbul. The catchment area for procurement was wide, for as John Ayers expressed it, the Ottoman Empire:[95]

> extended over much of the Middle East and beyond, reaching at its height almost from the Caspian Sea to Tangier and to the gates of Vienna; and withdrawing from North Africa and Europe only in the nineteenth century.

Through years from the +15th to the early +20th centuries, more than 10,000 pieces of Chinese porcelain were acquired for the palace, a large number by *muhallefat* or confiscation from estates of individuals resident in Turkey, Persia, Syria, Iraq, Egypt, Cyprus and Greece. All the Chinese porcelain in the Topkapi was for use in ablutions, rituals, at table or in the royal kitchens.[96] The majority comprised large, impressive pieces suited to Ottoman dining and cooking requirements. In many respects they were quite dissimilar to most Chinese export wares sent to Asia and Africa.

Chinese Ceramics in Africa

Trade with cities in North Africa started early. Fustat (Old Cairo) in Egypt was active from +642 to *c.* +1450. Ceramics reached there via overland transport routes from ports on the Red sea coast. Such was the importance of the site, and so thorough has archaeological excavation been there, that Fustat may be used as an exemplar of cultural and commercial relations between China, West Asia and Africa.[97] Thousands of sherds have been unearthed.[98] Thang and Five Dynasties

[94] To give just one example, the site of Qal'at al-Suhâar on the Gulf (in Oman) furnished 649 sherds of +9th- to +20th-century date. Of this number, over 25% dated from the +9th to +12th centuries, comprising Yüeh ware, white and *chhing-pai* wares. A large number of storage jars of all periods was balanced by a very small showing of export wares of +14th- to +17th-century date, mainly Lung-chhüan 龍泉窯 and blue-and-white. More than 50% was of +19th- and +20th-century date, indicating that the thriving export of 'kitchen ware' to South-east Asia went further to Arabia, and even Africa. Pirazzoli-t'Serstevens (1985), pp. 318–20. For surveys of the Yemen material see Hardy-Guilbert & Rougelle (1995), (1997).

[95] Ayers (1984), p. 77.

[96] The extant collections comprise: over 1,300 celadons of +14th- to +15th-century date, mostly from Lung-chhüan; over 53,000 items of blue-and-white of +14th- to +18th-century date, including pieces embellished with jewels by the Ottomans; over 700 monochrome porcelains of +15th- to +18th-century date, including some embellished with jewels; over 2,500 enamel-decorated artefacts of +16th- to +18th-century date; 148 'Swatow' wares; 14 Te-hua 德化 pieces; a small number of Vietnamese pieces of +15th- to +16th-century date; 294 items of late +19th- to +20th-century date; and a few miscellaneous items. For detailed, illustrated catalogues of the collection see Krahl & Ayers (1986), esp. list in vol. 1, p. 17. See also Raby & Yücel (1986), and Yücel (1986).

[97] Mikami (1982), p. 68.

[98] A forthcoming publication by Japanese archaeologists, for example, will catalogue 8,000 sherds, Yuba Tadanori (pers. comm. February +2001). Besides those maintained in Egypt, some are to be found in collections abroad, including at the British Museum and the Victoria & Albert Museum.



Fig. 162 Chinese Yuan dynasty porcelain vase decorated in underglaze-blue, with Turkish silver mount, in the Topkapi Saray Museum

wares comprised *san-tshai* 三彩, whiteware, Yüeh ware and Chhang-Sha wares, with local Egyptian wares appearing alongside them. From the Sung dynasty came celadons from Yüeh, Lung-chhüan and kilns in Fukien province, white and *chhing-pai* 青白 wares from Ching-te-chen and Fukien, plus brown wares from Fukien and Kuangtung provinces. The Yuan and early Ming periods provided whitewares, blue-and-white and miscellaneous other finds.[99]

It is notable that Chao Ju-Kua (+1225) recorded trade in porcelain with Zanzibar.[100] Archaeological excavation and chance recovery have confirmed that ceramics were exported to several points on the east African coast from the late Thang period onwards.[101] Clusters of sites near Djibouti, Kismayu and in Somalia; Lamu, Malindi and sites down the Kenyan coast; and Pemba Island, Zanzibar and sites along the Tanzanian coast, have all yielded sherds.[102] From the Thang and Five Dynasties periods whitewares, Yüeh wares, and decorated wares from both Chhang-sha in Hunan and Chhiung-lai 邛崍 in Szechuan provinces were common. For the Sung and Yuan dynasties ceramics from Chekiang, Fukien and Kuangtung provinces were the norm, while during Ming and Chhing dynasties supplies of celadons, Te-hua wares, blue-and-white and enamelled 'kitchen' wares continued to be sent.[103] It can be seen that in many respects exports to Arab kingdoms in East Africa mirrored those to destinations in South-east and West Asia.

Ceramics from West Asia Inspired by Chinese Export Wares

Wares from East and South-east Asia (particularly Korea, Japan and Vietnam) can be placed in the category of local imitation, where a natural abundance of high-firing clays, the use of cross-draught kilns, and the exploitation of wood ash as a glaze material, helped hasten the transfer of technology. This situation is in marked contrast to the early ceramics from West Asia that were inspired by Chinese export wares produced some 5,000 miles away. In this situation no general geological similarity was in place to assist the craftsmen, and there were no local high-fired traditions to build on. There also seems to have been little or no contact with Chinese potters to speed the process.

The early period of interaction between China and West Asia was the +8th to +10th centuries. Chinese wares imported during this period included clay-rich white porcelains and stonewares from north China, north Chinese *san-tshai* wares made to Near Eastern taste, as well as masses of greenwares, Chhang-sha wares, and *chhing-pai* porcelains from a range of southern sites. In the late +8th to early +9th centuries, some efforts were made in Iraq to develop tin oxide-opacified glazes in order to

[99] Mikami (1982), pp. 68–9.
[100] *Chu Fan Chih*, ch. 1, p. 24b.
[101] For an account of China's relations with Africa, see Needham *et al.* (1971), pp. 494–503.
[102] Ma Wen-Khuan & Meng Fan-Jen (1987), pp. 7–29.
[103] *Ibid.*, pp. 37–55.

evoke the characters of imported Chinese ceramics, particularly the white porcelains, white stonewares and polychrome Chhang-sha wares (see Fig. 47).[104]

The bodies for all these Near Eastern imitations were simply the fusible calcareous clays of the region, already used for more than four millennia for the making of ceramics.[105] Such clays show natural calcium carbonate contents from about 25 to 55%. They distort at about 1,100°C, and by 1,200°C will fuse into greenish glasses, their ultimate compositions being reminiscent of ferruginous Chinese ash-glazes.[106] Similar copies of Chinese wares, made from lower calcia, but still fusible, local clays, were produced at Fustat in northern Egypt but, because of their fragile and low-fired natures, few Islamic wares from this period have survived complete. Chinese museums by contrast are full of whole examples of the tough and strongly mullitised Chinese wares of the period, with their hard glazes looking today much as they did when drawn from their kilns, more than 1,000 years ago.

Two studies have sought to compare Near Eastern and Chinese ceramics analytically, to provide compositional evidence for differences already familiar from optical examination. In the first study, Chinese *san-tshai* sherds from Mantai in Ceylon, Fustat in Egypt and Samarra in Iraq were analysed, and then compared with Islamic versions of *san-tshai* ware from Samarra.[107] The results of both analytical studies showed clear differences in body composition. Chinese wares, probably from Kung-hsien 鞏縣 in Honan province and one other unidentified centre, had high-alumina, relatively low-iron clays typical of north China's geological domain. Islamic sherds were calcareous clays with high iron and magnesium contents, typical of alluvial materials derived from the Euphrates, Tigris and Nile river basins. The glazes were also dissimilar. Chinese *san-tshai* had typical high lead, significant alumina and almost no alkali, and were coloured with copper and iron (see pp. 500–3). The Islamic wares were medium-lead, significant in alkali and lime with opacifying tin, and coloured with copper and tiny amounts of cobalt.[108] In the second study, based on sherds from Samarra alone, comparison of Chinese *san-tshai* and Islamic splashed sgraffito ceramics confirmed the results of the first paper. Further comparative analysis of Chinese Chhang-sha wares from Hunan province was then made with Islamic glazed wares. The Chhang-sha pieces were all non-calcareous, with relatively low iron and magnesium, but contained considerable fine quartz, together with lesser amounts of volcanic glass and feldspar. Again, the Islamic wares were clearly differentiated, being calcareous and with high iron and magnesium.[109]

[104] Allan (1991), p. 6.

[105] Al-rawi *et al.* (1969); Matson (1985), p. 65, table II; Freestone (1991); Fleming *et al.* (1992), p. 215, table 1; Zhang Fukang (1992), p. 384, table 1; Simpson (1997b), p. 54.

[106] See, for example, the calcareous blackware glazes from Te-chhing 德清, Chekiang province, in Wood (1999), p. 139, table 51. These show compositions very similar to Mesopotamian earthenware clays.

[107] Rawson *et al.* (1989), pp. 39–61.

[108] *Ibid.*, pp. 49–51.

[109] The site at Samarra is discussed, and full analytical results with tables provided, in Fleming *et al.* (1992), pp. 211–22.

One important technical outcome from this period was the popularising of tin-glazed earthenware. That material eventually spread throughout the Near East, and then to Spain, and thence to the rest of Europe, Scandinavia, and to the New World. The diffusion of tin-glaze technology, with many tin-glazed vessels copying successive styles of imported Chinese porcelain, has been one of the great themes of Old World ceramic history.

ORIGIN OF TIN-OPACIFIED GLAZES

The use of between about 6 and 12% of tin oxide (SnO_2) to render earthenware glazes white and opaque appears to have been a Mesopotamian discovery of the late +8th century.[110] The first tin glazes in Iraq appear to have been used for four distinct purposes. Two of these relate to Chinese wares, and two to Mesopotamian innovations. In the first category are: local copies of imported Chinese whitewares, from the porcelain and stoneware kilns of north China; and copies of Chhang-sha polychrome stonewares from south China, especially those with green, brown, and purple- brown ash-glazes on white-glaze grounds. Distinctly local uses for early tin-glazes in Iraq include grounds for lustre wares, and also for painting with cobalt-blue glazes and pigments.[111] Old Basra has been suggested as the main production site for these more varied types, while Baghdad mainly made plain white tin-glazed wares.[112] Lustre ware eventually became the leading ceramic technology of the Near East and this was a technique without precedent or parallel in China.

It seems possible that much of the tin oxide used in tin-glazes dissolves as the glaze melts, and then precipitates to a state of near-colloidal fineness.[113] This would help to explain the combination of opacity with good surface smoothness characteristic of the best tin glazes. The effect is superior to the dull surfaces usually created when suspended or crystallised material is used to render a glaze opaque, which was the standard approach to making opaque 'white' glazes in West Asia before that time. In this respect there are technological parallels between tin-glazes and the 'colloidal white' stoneware glazes of the Chhang-sha

[110] Mason & Tite (1997), pp. 48–52. Old Basra (ten kilometres west of present-day Basra) seems to have a major site for the early use of tin-oxide-opacified glazes on ceramics, with +800 sometimes given as a date when the technology became fully developed in the area. Mason & Tite (1994a), p. 34. See Tite *et al.* (1998), p. 244, table 2, for a range of Near Eastern and European tin-glaze compositions. With regard to the amounts of tin oxide used in these glazes, Vendrell *et al.* (2000), p. 325, note: 'In ancient ceramics, the concentration of tin oxide varied from 3–4% (Iraq in the 8th C AD) up to 20–25% (Italy in the thirteenth century AD), but the opacification is usually achieved with concentrations between 5 and 10%.'

[111] Tamari (1995), p. 140, notes: 'Two application methods were used . . . In one, the method was simply to paint the design with a . . . pigment over the opaque white glaze, while in the other, the cobalt was mixed with a lead/tin glaze, producing the motif in slight relief, in the form of thick layer above the glaze.' Compare Kleinmann (1991) with Chen Yaocheng *et al.* (1995b).

[112] Mason & Tite (1997), p. 49.

[113] Tite *et al.* (1998), p. 256; Vendrell *et al.* (2000), p. 326.

kilns that some of these earliest tin glazes imitated, as these too exploited 'optical white' phenomena.[114]

STONE-PASTE AND SOFT-PASTE BODIES

By the +11th to +12th centuries, efforts to mimic the whiteness and translucency of imported Chinese Sung dynasty porcelain led to a major innovation. Calcareous clays are entirely non-translucent, but a further influence of Chinese ceramics at this time was the move towards whiter and more translucent bodies, largely from kilns in southern China. Traditional potters in the Near East confronted by southern Chinese porcelains but unaware of the true nature of the material, would immediately have recognised the use of conventional pottery-making methods. They included throwing and turning, or moulding by pressing, and all showed that a clay-like material was involved. They would also have seen affinities with glass in porcelain's unusual translucency. Broken southern porcelains, of the rougher *chhing-pai* types, would have tended to look granular, with their high quartz contents appearing rather obvious.[115]

Given these visual clues it is perhaps not surprising that combinations of quartz, powdered glass and light-firing clays became popular methods for making superficial copies of imported Chinese wares, particularly porcelains. Potters in Egypt, and subsequently in Persia, Syria, Iraq and Turkey, refined a technology that had its origins in Egyptian faience as far back as *c.* −4,000. One essential ingredient, a constituent of both bodies and glazes, was an alkaline glass frit. This was obtained by burning desert plants that provided mainly soda (Na_2O) but also some potash (K_2O), lime and magnesia (see Table 64, p. 459 [ash analyses]), and then melting the ash together with about 50% crushed quartz pebbles. The resulting glass was pulverised by grinding or by being poured when molten into cold water. This frit (which made up about 10% of the body-material) was mixed with the major constituent, pure quartz, again derived from pebbles ground to a fine powder. 10–20% of very fine white clay was the third addition, rendering the body plastic enough for forming. The resultant quartz-frit-clay ceramic was for Islamic potters the equivalent of

[114] Zhang Fukang (1987); Zhang Fukang (1989). Ho & Bronson (1987), pp. 75–7, believe that Chhang-sha multi-coloured wares were first made in China in about +800 and they note, of the Chhang-sha kilns: 'Their non-representational painted wares had an especially strong impact on Middle Eastern ceramic production . . .'. Fleming *et al.* (1992), p. 217, give a particularly early date for finds of polychrome decorated Chhang-sha wares in the Near East, namely +803, from beneath the floor of the Great Mosque at Siraf on the Iranian shore of the Gulf. This would bring the beginnings of tin glazes in the Near East very near to the first substantial imports of Chinese wares to the region.

[115] What would not have been apparent, even from the most careful visual inspection, would have been the felted mass of needle-shaped mullite crystals that tend to develop in high-temperature ceramics, and which give stonewares and porcelains such impressive strength. The mullite is a largely a product of the high-temperature breakdown of aluminous minerals, such as clays and potassium micas, particularly above 1,150°C. Some glass too is supplied by the micas, with further glass provided by the melting of any feldspars present in the clays. It is largely this combination of viscous body-glass with mullite that explains the fired strengths of stonewares and porcelains, with strong mullite development in particular distinguishing low-fired from high-fired ceramics.

porcelain.[116] In Europe these wares tend to be called 'soft-pastes', 'soft' being a potter's term for 'low-fired'. For Islamic ceramics the term 'stone-paste' is now preferred, as a translation from the Persian.[117] This Islamic material pre-dates the European, and its origins were explored by Robert Mason and Michael Tite at Oxford in the early +1990s.[118]

Mason and Tite propose that Islamic stone-paste material may have been developed by migrant Iraqi potters in Egypt in the +10th to +11th centuries, after some initial experiments with adding powdered glass to clay bodies in Iraq in the +9th century. The first Egyptian versions of this approach served as bodies for finer lustre wares, a technology newly transferred to Egypt from Iraq. These improved bodies were made from calcareous clays enhanced with quartz sand and powdered glass: 'perhaps enabling confusion with imported stonewares'.[119]

Nonetheless, clay still dominated in the 'proto-stone-paste' recipes and the results were buff-firing rather than white. The change to true stone-paste happened when less clay and more quartz gave whiter bodies that were suitable for making acceptable copies of imported Chinese wares, as well as serving as fabrics for the finest lustre-wares. This change has been placed provisionally to the period +1025 to +1075. Mason and Tite suggest that a surviving use of quartz-based glazed-bead technology at Fustat may have helped in this crucial change from clay-rich to quartz-rich bodies, but: 'the technological foundation for stone-paste, and its logical progenitor, was proto-stone-paste.'[120]

Such glass-fluxed ceramics are weak, as they are essentially white earthenware materials. They also have a poor resistance to thermal shock. Raising their glass contents to give more strength or true translucency made distortion in firing hard to avoid, as soda-lime glass has low viscosity. Little or no mullite forms in these materials (fired typically to between 1,000° and 1,050°C for Islamic wares) and the glazes used with them are of the soft earthenware type. Nonetheless this was the main method for copying Chinese porcelain from the +11th through to the early +18th centuries in both the Islamic world and in Europe.

From Egypt, these new white stone-paste bodies spread eastwards to Iran and to Syria in the later +11th century, where they proved effective for copying siliceous south Chinese porcelains such as *chhing-pai* wares. Extra translucency was sometimes managed by perforating the bodies and filling the holes with glaze. Similar bodies were also used for the first Islamic underglaze-blue wares, such as those made in Raqqa and Damascus in Syria in the +12th century, as well as for lustre wares and *sgraffito* wares. These latter wares often imitated imported Chinese originals such as *chhing-pai* porcelains and southern celadons.[121]

[116] Kingery & Vandiver (1986a), pp. 9–12, 19, 37, 112–16.
[117] Hamer & Hamer (1997), p. 322; Mason & Tite (1994a), pp. 34–5.
[118] Mason & Tite (1994b).
[119] *Ibid.*, p. 88.
[120] *Ibid.*, p. 90.
[121] Mason & Tite (1994a), pp. 35–6, note: 'Unlike Raqqa, where production appears to have ceased after it was sacked by the Mongols, Damascus continued to rank foremost in the production of Islamic ceramics for many centuries afterwards.'



Fig. 163 Panel of tiles, fritware with lustre decoration and turquoise glaze, from Iran (Kashan), +13th – +14th centuries

Composition, Forming and Firing Techniques of Stone-Paste Wares

Just as in China, Islamic texts recorded composition, forming and firing techniques of ceramics. One of the best-known accounts was that of Abu'l Qasim, member of Kashan's main ceramics-producing family (see pp. 663 and 678). In +1301 he described the composition of stone-paste ceramics as being ten parts powdered quartz, one part clay and one part soda-lime glass, and as being suitable for making, 'pottery objects and vessels such as dishes, basins, jugs, and house tiles.'[122]

[122] As Arab-ali Sherveh (1994), p. 10, notes: 'in Persian the name of the city, Kashan, and the word Kashi, has the same meaning – tile.'

Shaping the resultant fritware was not so different to Chinese porcelain manufacture as one might expect:[123]

[The paste] is kneaded well like dough and left to mature for one night. In the morning it is well beaten by hand and the mastercraftsman makes it into fine vessels on the potter's wheel; these are left standing until they are half dry. They are scraped down on the wheel and the feet are added.

Kilns used to fire such wares were updraught, domed structures consisting of a lower and sometimes subterranean firebox chamber, and an upper firing chamber to contain the pots. Heat passed from the fire through holes into the upper chamber, circulated and then dispersed through more perforations in the roof. Saggers were sometimes used, as was a singular form of firing support. This consisted of long cylinders of refractory clay, set in rows into the kiln walls. Ceramic pegs have been found at many sites, often with traces of glaze adhering to them. However, the exact disposition of pots and pegs in the kiln is open to discussion.[124] Islamic kilns used oxidising firing for successful results, as Abu'l Qasim made clear:[125]

Vessels are placed on [ceramic pegs] and fired for twelve hours with a hot even fire, with this stipulation that no wood be put on until the smoking has stopped, so that smoke does not ruin or blacken the pots. In Kashan they burn soft wood (like hyssop and walnut) and in Baghdad, Tabris and other places the wood of a willow stripped of its bark so that it does not smoke. The vessels are removed from the kiln after a week, after they have cooled.

Decorative Techniques Linking China and the Near East

Another technique that originated in Egypt, was the +8th-century ornamentation of glass with lustre. By the +9th century its use had extended to the lustre-glazing of pottery, whereafter it developed into the leading ceramic technology of the Near East. Lustre was an overglaze technique that used pigments compounded from silver and copper compounds, finely ground together with a clay medium. This pigment was painted on to pre-fired and glazed ceramics, and then fired at a low temperature so that the underlying glaze softened but did not completely melt, and the clay medium did not bond with it. Mild reduction firing ensured that carbon monoxide gases in the kiln extracted oxygen from silver and copper compounds, that had converted to oxides in the first phase of firing (for reduction firing, see p. 296), a process perhaps assisted by the use of sulphides, organic materials and, in some cases, mercuric compounds in the lustre pigments. The metallic compounds were deposited as a thin layer bonded into the surface of the glaze, and subsequent polishing away of

[123] Abu'l Qasim's text has been translated by Allan (1973), here pp. 113–14. The passage is quoted in Watson (1985), pp. 32–3.
[124] A suggested kiln reconstruction is shown in Porter (1995), p. 12, along with a clear photo of an excavated kiln with peg-holes in the kiln wall, on p. 10.
[125] Allan (1973), p. 114, also quoted in Porter (1995), pp. 11–12.

the clay medium revealed an extremely thin layer of lustre, about one micron in thickness. The thinness of the lustre layer, and the foil provided by its white, tin-opacified glaze ground, produced multi-coloured, iridescent hues that were much admired.[126] It was generally considered that Chinese potters ignored lustre-glazes. However, careful examination by Chinese archaeologists of porcelain from the Yuan dynasty imperial kiln at Ching-te-chen has led them to believe that rudimentary attempts to reproduce lustre ware were being made there, albeit using entirely different technologies.[127] The Yuan dynasty was a time when China was open to influence from other lands in the greater Mongol empire. It was the period when turquoise glazes, also pioneered in West Asia, were copied by some Tzhu-chou kilns 磁州窯 in north China, and used for the first time at Ching-te-chen in the south.

Stone-paste technology was adapted and improved in Turkey in the late +15th / early +16th century for the famous Isnik wares. In Turkey lead oxide was included in the body-glass for the first time, and the quartz prepared for the body was extremely fine-ground, and an even finer siliceous slip was also employed.[128] The use of lead oxide in both bodies and glazes in Isnik wares encouraged superior glaze-fit and the pure and fine quartz further improved the whiteness of the fabric. In the +16th century this very successful Turkish stone-paste material was used to copy Chinese underglaze-blue export wares, often borrowing elements from +14th-century Ching-te-chen painted designs. Strong underglaze colours, based on oxides and slips, were also devised by Isnik potters to give polychrome stone-pastes, with a colour-range that became even richer than Chinese enamelled porcelains.[129] In their fineness and whiteness of material, Isnik wares can be regarded as representing a transition from stone-paste to soft-paste porcelain, and paved the way for the often very translucent late +17th century and early +18th-century Gombroon wares of Persia that can be regarded as the culmination of the Islamic stone-paste evolution.[130]

[126] For fuller descriptions of lustre-glaze technology see Watson (1985), pp. 31–2; Kingery and Vandiver (1986a), pp. 11–12, 111–21. Abu'l Qasim described lustre production in +1301, see Allan (1973), p. 114.

[127] Scott (1992), pp. 47–8. One should note, however, that attempts to fire single layers of gold leaf on porcelain (see p. 704) might have given lustre-like effects.

[128] Tite (1989), pp. 120–5. Henderson & Raby (1989), pp. 121–2, place the first use of lead-containing body-frits in Turkish tiles to the +15th century.

[129] Tite (1989), pp. 125–8.

[130] 'Gombroon was the old name for the port of Bandar Abbas. Here the Dutch East India Company had a trading station, and from Gombroon quantities of Persian soft-paste porcelain were shipped to Europe.' Alan (1991), p. 64.

CHINA'S TECHNOLOGY TRANSFER TO THE WORLD AND THE SIGNIFICANCE OF CHINESE CERAMICS IN THE CONTEXT OF WORLD CERAMIC TECHNOLOGY: 2

REMOTE TRANSFER: THE INFLUENCE OF CHINESE CERAMICS IN EUROPE

EUROPEAN KNOWLEDGE ABOUT CHINA AND CERAMICS IN THE +16TH AND +17TH CENTURIES

During the +16th and +17th centuries close links existed between European maritime expansion, religious proselytising, and commerce. Missionary activities were pursued with ardour by the clergy, while officials and merchants were eager to further trade by any means. Many European records of China were made by missionaries, like that of the Dominican friar Gaspar da Cruz who composed *Tratado em que se Contam muito por Estenso as Cousas da China com as Suas Particularidades e assi do Reyno de Ormuz* (Treatise in Which the Things of China and Their Peculiarities as Well as Those of the Kingdom of Ormuz are Related in Great Detail) in +1569.[131] This account quickly circulated outside Portugal, although its contents were paraphrased and recycled by other authors like the Spanish missionary Juan González de Mendoza.[132] In this respect, early Western accounts of China have some points of conceptual similarity with contemporary handbooks on connoisseurship written by Chinese scholars. The latter compiled books whose contents borrowed freely from one another, often quoting whole passages *verbatim*, while at the same time using predecessors' work to support their own discourse.[133]

The work of another Portuguese missionary monk, Father Alvarez Semedo, was also promulgated to a wide public. Semedo wrote a description in Latin of China in +1638 that was quickly translated into English in +1655.[134] Father Semedo's account was not by any means the earliest Western record of China, but it was one of first to reach an English-speaking audience. Both Cruz's and Semedo's knowledge of China resulted from Portuguese mastery of the great ocean voyage down the Atlantic coast of Africa; around the Cape of Torments (or Tempestuous Cape, and

[131] Pinto de Matos (1999), pp. 95, 111, 124. This work was discussed by speakers at the symposium in Lisbon in November +1999, 'Legacy of Macao', whose papers were subsequently published in *Oriental Art* vol. 46, no. 3 (2000). See Carvalho (2000), Pinto de Matos (2000) and Loureiro (2000).

[132] Loureiro (2000), p. 63.

[133] Clunas (1991), pp. 9–10, quoting van Gulik (1958).

[134] The translation was undertaken for John Crook, to be sold at his shop at the Sign of the Ship in St Paul's Church-yard in London. It is written in the beautiful, rolling language of the King James Bible, in +17th-century English.

renamed by King Manuel I as the Cape of Good Hope); across the Indian Ocean to India, guided by Arab pilots, and first reached in +1498; on to Ceylon; through the straits of Malacca whose principal port was conquered in +1511; and finally across the China Sea to the southern ports of China, attained by +1513.[135] This marathon journey, pioneered by mariners and merchants in search of trade, enabled religious orders to travel to China and pursue their missions there.

Prior to the +16th century, porcelains had only reached Western Europe in small numbers, and individual items were highly prized. One of the first documented pieces known to have reached Europe is the Fonthill Vase, a Yuan dynasty *chhing-pai* 青白 piece sent from the court of the last Mongol emperor by an embassy to Benedict XII, third pope at Avignon, in +1338. The vase was transformed with European silver-gilt mounts and enamels, bearing the arms of Louis the Great of Hungary (+1326–1382), into a ewer. A detailed watercolour of *c.* +1713 (now in the Bibliothèque National in Paris) of this bottle with its mounts is the most important surviving illustration of early European mounting of Chinese porcelain.[136] Other historic porcelains in Western collections included those recorded as being in the collections of the Duke of Normandy in +1363, the Duc de Berry in +1416 and Charles VII of France in +1447. A celadon bowl embellished with a gothic base for Duke Philip von Catzenellebogen between +1434 and +1453 survives in the Landesmuseum, Kassel.[137] In +1461 Doge Pasquale Malipiero of Venice received twenty pieces of porcelain from the Egyptian sultan.[138] In +1487 Lorenzo de Medici, *il Magnifico*, received porcelain from Egypt.[139] An early +16th-century Chinese bowl in a Renaissance mounting is said to have been presented by Archbishop Warham (+1504–1552) to New College, Oxford, around +1539.[140]

The chief factor about such porcelains that intrigued scholars and collectors was what the material actually comprised. Various theories had been advanced: that it was some sort of precious stone; that it was a 'certain juice' that coalesced underground; or that it was crushed eggshells and seashells mixed with water. In the mid +16th century two Italian scholars, Cardan and Scaliger, espoused these views, which were based on earlier accounts by Duarte Barbosa, a member of the Portuguese overseas mission in the +1510s.[141] The shell theory remained in

[135] In fact, early Portuguese travellers reached China in Indian or Chinese ships; the first Portuguese ships did not reach China till +1521. Sebes (1993), pp. 35–40.

[136] See Lane (1961), pl. 3.

[137] Anon. (1990), *Porzellan aus China und Japan*, pp. 216–18.

[138] Cronaca Sanuda, Biblioteca Naz. Marciana, Cod. It. VII 125 [=7460], c.319r. The authors are indebted to Robert Finlay for this reference.

[139] Sargent (1994), p. 2.

[140] Scheurleer (1974), pp. 42–3.

[141] Lightbown (1969), pp. 230–1. Duarte Barbosa, together with his fellow civil-servant Tomé Pires, who had also travelled to Asia, prepared two global treatises during +1515–16 to satisfy intense interest in the region. They were the *Suma Oriente* and the *Livro das coisas do Oriente*. It was the latter work, published in +1517 and preserved in the National Library in Lisbon (BNL, Secção de Reservados, cod.11008, fl.63), which contained the reference to the composition of porcelain. See Pinto de Matos (2000), pp. 66, 75.

public perception for a long time, for as late as +1646 it was still being propounded by Thomas Browne, an English doctor from Norwich.[142]

A curious fact about many of these fanciful accounts is that they emphasise that vessels made from whatever 'magic mixture' be buried underground for lengthy periods of time; some authorities mention 100 years, others only 40–50. The English scholar Francis Bacon, for example, in his *Novum Organum* of +1620, cites the Chinese method of making porcelain by burying earthenware under ground for 40 or 50 years.[143] It is tempting to think that this idea was influenced, however distantly, by descriptions of the actual craft of pottery-making in China. There, pits or large storage jars were used to store clay after preliminary preparation. This allowed the clay to ferment or rot, producing higher-quality clays (see p. 440).[144] Clays were stored for a matter of months rather than years, however. Another practice was for individual potters to lay down good-quality clays in specially dug pits, for their sons to inherit. This appears to have been a custom at some kilns in China,[145] and is a system that still operates in contemporary Japan.[146]

Missionary Accounts of China and Chinese Porcelain

Although we have seen that Western understanding of the nature of porcelain was confused, it should nonetheless have been possible for some correct information about porcelain-making to have reached Europe in the +16th to +17th centuries.[147] This is because long before Dr Thomas Browne of Norwich was propounding his crushed-shell theory there were reasonably accurate reports of porcelain-making from missionaries. Gaspar da Cruz, who only got as far as Canton, was nonetheless able to pen descriptions of porcelain-making and the place that porcelain came from:[148]

> There is another province called Quiansi [Chiangsi] . . . and it is there that all the fine porcelain is made, from Sulljo [Ching-te-chen] . . . and none is made anywhere else . . . and because there are many opinions among the Portuguese who have never been to China about where the porcelain is made and what material it is made of, some saying that it is made from the shells of oysters and others from long-rotten manure, because they do not

[142] Keynes (1928–31), vol. 2, pp. 154–5.
[143] Bray (1857), vol. 4, p. 237.
[144] Li Dejin (1994), p. 38.
[145] For example, at Te-hua 德化, pers. comm. from Chhen Chien-Chung 陳建中, Director of the Te-hua archaeological management committee.
[146] Information provided about clay inherited by the present head of the Raku family, Raku Kichizaemon XV 樂吉左 衛門 XV, in a lecture given by Rupert Faulkner to the Oriental Ceramic Society in London on 5 December, +2000.
[147] Research on this topic published in Kerr (2001).
[148] Translated and included in Pinto de Matos (1999), p. 111, and (2000), p. 66.

know the truth, it seems to me to be helpful to say here what porcelain is made of is a white, soft stone. . .

Another information-gathering enterprise was the map-making exercise undertaken by Father Michele Ruggieri, the first Jesuit to set foot in China, in +1581. Ruggieri established the earliest mission in China together with Matteo Ricci, spending the years +1585 to +1588 at Chhao-chhing 肇慶 in Kuangtung province. Although, like Cruz, Ruggieri never travelled outside this southern province, he was able to glean enough information about other regions of China to compile maps of:[149]

Hai-nan Island 海南島
Kuangtung province 廣東省
Fukien province 福建省
Chekiang province 浙江省
the province around Peking 北京地區
Shensi province 陝西省
Shansi province 山西省
Shantung province 山東省
Yunnan province 雲南省
Szechuan province 四川省
Kweichou province 貴州省
Honan province 河南省
the province around Nanking 南京地區
Chiangsi province 江西省

Naturally, Ruggieri's maps varied in accuracy and detail, but the map of Chiangsi province showed the position of the provincial capital, Nan-chhang 南昌, and that of the large city near Ching-te-chen 景德鎮, Jao-chou 饒州, approximately correctly. It also illustrated a body of water that we may presume to be the Pho-yang lake 鄱陽湖. It did not, however, show the porcelain-making city of Ching-te-chen itself.

The account by Juan González de Mendoza mentioned above, originally published in +1585 and translated for publication in English by +1588, described the variety and low cost of ceramic vessels available in shops in China. González de Mendoza's description of porcelain manufacture was accurate, and echoed the earlier account by Cruz:[150]

they make them of very strong earth, which they break all to pieces and grind it, and put it into cisterns with water, made of lime and stone. After that they tumble and toss it in the water and the cream on the top makes the best ware. The lower they go, the coarser is the material. They make vessels in the same forms and fashions as we do here, and afterwards they gild them, and make them what colour they please, and the colour will never be lost.

[149] The maps are illustrated, with commentary, in *Atlante Della Cina di Michele Ruggieri, S.I.*
[150] Gonzales de Mendoza (1588), ch. 10, pp. 22–3.



Fig. 164 Map of Chiangsi from *Atlante della Cina di Michele Ruggieri S.J.*, information gathered in China +1585–8, published +1606

Then they put them into their kilns and burn them. This has been seen and is true, unlike a book in Italian by Duarte Barbosa, which says that they make porcelain of periwinkle sea-shells which they grind and put under the earth to refine them for 100 years . . . But if that were true, they should not make so great a number of them as is made in that kingdom.

Father Alvarez Semedo wrote similar remarks in +1638:[151]

the Province of Chiangsi . . . is famous . . . and more for the *Porcellane* dishes (indeed the only work in the world of this kind) which are made only in one of its towns. So that all that is used in the kingdom, and dispersed through the whole world, is brought from this place. The earth they are made of comes from another place. There only is the water, with which they are made to perfection, for if they use any other water the work will not have so much gloss and lustre. In this work there are not those mysteries that other people have written about, neither in the matter, the form, nor the manner of working. They are made absolutely of earth, but of neat and excellent quality. They are made in the same time, and in the same manner, as our earthen vessels; only they make them with more diligence and accurateness.

[151] Semedo (1655), p. 12.

Several early manuscripts contained written information about Chiangsi province: for example, the account in German by Father De Mandelslo of +1639:[152]

> The special thing about the province of Chiangsi is that that is where they make all the porcelain that one sees the world over. All those pieces are made at a single village in the vicinity of the town of Fu-liang; out of a soil or clay that is brought from the town of Hua-shih in the province of Chiang-nan or Nanking . . .[the soil] is white like chalk, but a bit transparent like sand, and they tread it for several days to reduce it to a paste . . .

The germs of correct information are confused here. The term *hua-shih* 滑石 was later explained by Père d'Entrecolles to be the fine, kaolin-rich slip used in the manufacture of super-fine porcelain (see p. 228). The myth that porcelain came from Nanking has been used in several Western books, down to the +20th century.

Export of Chinese Porcelain to Europe

It is thus demonstrable that by the second half of the +16th century accurate descriptions of materials used to make porcelain, together with descriptions and maps of the major area where it was produced, were available in Europe. The demystifying nature of these reports was augmented by the fact that, first the Portuguese, and then the Dutch, brought ever-increasing numbers of porcelains to the West during the course of the +17th century. In +1615 the Dutch shipped about 24,000 items of blue-and-white, in +1616 around 42,000 and by +1638 it has been estimated that over three million pieces of porcelain had been transported to Europe by the Dutch.[153] During the first half of the century these wares came mainly from China, but following the collapse of the Ming dynasty and ensuing civil ware, from +1657 until about +1683, the trade switched to Japan.[154] These trade porcelains were made for domestic use in Europe, and while the finest of them served for display purposes, sets of items were increasingly utilised as domestic tablewares.

By the time the +17th century came to an end, trade with China was actively pursued by many European countries. Among the most determined and aggressive were the British. The English 'Honourable East India Company' was not so named until +1708, though its origins may be traced back to a monopoly company operating as early as +1600. By the +1730s the English Company had achieved supremacy in trade with China and was bringing back hundreds of thousands of pieces of Chinese porcelain to sell on the London market.[155]

[152] De Wicquefort (1666), pp. 476–7.
[153] Impey (1977), p. 92.
[154] Jörg (1982), pp. 91–2.
[155] Howard (1994), pp. 13, 15, 21. To the official cargoes must be added large private orders commissioned by the captains, officers and supercargoes of Company ships. In spite of the huge quantity of wares shipped, it should be emphasised that porcelain was not of great significance in terms of value or share in the Company's total trade. The highest share ever achieved was 20% of the total, while normally it never exceeded 12%, see Chaudhuri (1978), p. 407. The regular arrival of very large numbers of Chinese porcelains led to their becoming a commonplace in well-to-do British homes. Whole dinner services graced the tables of the gentry, cups and saucers were employed for the newly fashionable habit of drinking tea, while garnitures of vases and jars were used for ornamental use in an architectural context, see Somers Cocks (1989), pp. 195–215.



Fig. 165 Chinese blue-and-white porcelain from the *Geldermalsen* stacked up in Christie's storeroom prior to its sale

Dramatic and tangible evidence of the scale of European trade in ceramics was provided by the +1984 recovery of a Dutch East Indiaman, the *Geldermalsen*. This ship sank in early January +1752, en route from Canton to Batavia (present-day Jakarta). On board was a quantity of gold, tea, currency, spices and 140,000 items of Chinese porcelain.[156] Research by Cristiaan Jörg among the archives of the Dutch East India Company indicates that the *Geldermalsen's* porcelain cargo should be seen as a typical shipment made by any of the active

[156] Sheaf & Kilburn (1988).

European East India Companies returning from China in the mid +18th century.[157]

By the late +18th century the success of European ceramic factories in copying Chinese products led to a diminution of trade. In England, for example, the success of the national pottery industry, together with several other factors such as changing British attitudes to China,[158] meant that after about +1780 bulk-imported Chinese ceramics failed to sell. In +1791 the English East India Company ceased trading in porcelain in its own right.[159] By +1820 European homes acquired their tablewares from European factories, though China continued to supply wares to North America.

Early Imitations of Chinese Porcelain in Europe

The origins of these later European successes in porcelain-making may be traced to the +16th century, following a growing appreciation for imported Chinese porcelains in the later +15th century. Lorenzo de Medici (the Magnificent, +1449–1492), for example, was a noted collector and his porcelains were dispersed two years after his death. Indeed one of the first, successful, short-lived attempts to copy Chinese porcelain in European workshops took place in Florence from about +1575 to +1587, under the patronage and encouragement of Lorenzo's great-grandson, the Grand Duke Francesco I de Medici (+1541–1587).

During the +15th and +16th centuries, trade had flourished between Italy, North Africa and West Asia. Chinese porcelain and Persian frit ware were among the imports, and the Medici trials were attempts to copy both. Minor differences from the stone-paste tradition included a higher proportion of plastic material in the paste, and the use of potassium oxide as a body-flux, rather than the traditional sodium and calcium oxides used in stone-paste wares. Nonetheless the Florentine soft-paste was essentially similar in its nature to Islamic stone-paste, and tradition has linked a 'Levantine' with its development.[160] Medici ceramic bodies were made up from fine sand, 15–20% white clay and glaze-maker's sinter.[161] The 'sinter' was a popular ingredient in contemporary Italian tin glazes, as recorded by Cipriano Piccolpasso in +1577.[162] Glazes contained calcined wine lees, sand, lead oxide and salt. So far as can be assessed, the body was biscuit-fired to about 1,100°C to render it translucent,[163] designs were painted in manganese and cobalt-blue, and pieces were

[157] Jörg (1982); Jörg (1986). See also Sheaf & Kilburn (1988), p. 97.
[158] Dawson (1967), quoted in Pearce (1989), pp. 30–1.
[159] *Ibid.*, p. 26. Cf. Chaudhuri (1978).
[160] Allan (1991), p. 74, writes: 'In 1575 the Venetian Ambassador to Florence wrote that the Duke "has equalled its [porcelain's] quality – its transparency, hardness lightness and delicacy; it has taken him ten years to discover the secret, but a Levantine showed the way to success."'
[161] Marzacotta, which was composed of sand, salt and calcined wine lees. Calcined wine lees contributed mainly potassium carbonate, with lime, silica and a little magnesium.
[162] 16th-century Italian ceramic technology is described by Cipriano Piccolpasso in his +1557 work *The Three Books of the Potter's Art*, trans. Ronald Lightbown & Alan Caiger-Smith.
[163] A temperature far in excess of traditional kiln temperatures of 950–1,000°C.



Fig. 166 Medici blue-and-white flask, *c.* +1575–87

then glazed with a soft lead-alkali composition that matured between about 900°C and 950°C.

The achievement of Medici soft-paste has been credited to the combined efforts of Bernardo Buontalenti (+1536–1608) and the majolica-maker Flamino Fontana (no dates known).[164] Although visually effective, the ware was expensive to make and almost always deformed during firing, and fewer than 60 examples of Medici porcelain have survived. Nonetheless Duke Francesco considered the material successful enough to present to fellow rulers, and a square-sectioned flask of Medici soft-paste porcelain, decorated with Philip II of Spain's coat of arms, was given to

[164] Rondot (1999), p. 19.

the Bourbon King in +1582.[165] Production appears to have ended with the death of the Grand Duke in +1587.

French Soft-Pastes

Following these early experiments in Florence, there is a gap of some 90 years before similar glass-based porcelain imitations appeared again in Europe, this time in France. They employed a similar technology, but arising from quite separate research work, to create the first European commercial ware to rival Chinese porcelain. This was soft-paste porcelain, invented as early as +1677 and produced at St Cloud in France from *c.* +1695, and also at Rouen. When analysed, its body revealed a composition based on both West Asian quartz-frit-clay ceramics, and European earthenware faience. It was formed from sintered alkali silica glass, 16.5% white limestone and 8.3% fine, calcareous marl clay from Argenteuil. The processing was carried out wet, and the resulting mixture then decanted, partially dried, wedged and stored for some months in wooden barrels. It could then be moulded, but required addition of a solution of black soap and parchment glue to give additional strength for throwing and turning.[166] Again, the raw materials and processes involved were quite different to those of East Asian porcelain, though they were inspired by Ching-te-chen blue-and-white porcelains, and also by Te-hua 德化 *blanc-de-chine*. The product was one of beauty, and its development stimulated research and manufacture of soft-paste porcelain elsewhere, some of which enjoyed commercial success.[167] But despite their sumptuous qualities they were soft and brittle in use, and very difficult to mould and fire, with some of the highest failure rates in ceramic history.[168] French soft-pastes were refined and improved throughout the +18th century, while remaining a technological *cul-de-sac* in European porcelain research.[169]

Meissen Porcelain

Chinese porcelain was at last equalled in Europe, and in many ways surpassed, at Dresden in Saxony in the first two decades of the +18th century. This was more than 1,000 years after its first appearance in north China. The vital research towards its

[165] The flask is now in the Museé National de Céramique, Sèvres, France.

[166] Information derived from Kingery & Vandiver (1986a), pp. 179–94.

[167] In England, for example, soft-paste or 'glassy porcelains' were made after +1745 at Chelsea, Derby, Longton Hall and West Pans. Its composition was somewhat different to that of French wares, being composed of quartz sand, clay, flint, lime-alkali glass and lime, with lead. Tite & Bimson (1991), pp. 3, 24.

[168] See Kingery & Smith (1985), pp. 173–92, and d'Albis (1999), pp. 35–42, for detailed technical accounts of early French soft-pastes and their problems in manufacture.

[169] The Saxon porcelain-pioneer Ehrenfied Von Tschirnhaus visited the St Cloud works in +1701, but noted that the various pieces he bought later 'fell apart by themselves'. Cassidy-Geiger (1999), p. 97. Delayed cracking ('dunting'), due to tensions set up in firing, can be a major problem in experimental bodies. For example, Josiah Wedgwood wrote to his partner Thomas Bentley, who ran his London showroom, in May +1776, that some of his early Jasper ware plaques could: 'crack along the Road, & in your Drawers too I dare say.' Reilly (1994), p. 83.

creation was carried out in the late +17th century by the mathematician and physicist, Ehrenfied Walther von Tschirnhaus (+1651–1708).

Von Tschirnhaus studied philosophy, mathematics and medicine at the University of Leiden in +1668–9. By the time his work on porcelain began, he had amassed a comprehensive knowledge of European science, both pure and applied, from travels in the +1670s in England, France, the Netherlands and Italy. Von Tschirnhaus had ambitions to found a scientific society in Saxony supported by new businesses based on the best modern knowledge. To these ends he studied glass- and mirror-making, and built a series of successful lens-grinding machines. As early as +1677 his interests were expanding to porcelain-work assisted by the construction and use of large burning-mirrors to test the fusibility of rocks and minerals, both alone and in combination.[170] This sound experimental background made Von Tschirnhaus an ideal figure to supervise the porcelain researches at Dresden of the one-time alchemist, Johann Friedrich Böttger (+1682–1719). Financial problems also led the Elector of Saxony, Augustus the Strong (+1670–1733), to commission Von Tschirnhaus to search Saxony for precious stones, a survey that must have sharpened the scientist's knowledge of Saxon raw materials. Augustus the Strong had initially recruited Böttger in +1701, after the alchemist's escape from Berlin, following a failure to substantiate his claims to make gold from mercury. Bottger's first assignment was to help Augustus' Superintendent of Mining, Gottfried Pabst von Ohain, but in +1705 his task was changed to porcelain research.[171]

One of the first successes of the Von Tschirnhaus-Böttger collaboration was a hard red stoneware, styled loosely on Chinese I-hsing ware, that could be finished on a lapidary's wheel, and a factory for its production was opened on the Venusbastion in Dresden in +1707. As the Venusbastion project outgrew its premises, operations were gradually moved to the Albrechtsburg castle near Meissen from +1710 onwards. The new site combined space with security, although its main operators worked there as virtual prisoners.

The First Saxon Porcelain

There is a workshop note to the effect that white porcelain was first made successfully on 15 January +1708, although Von Tschirnhaus died in October +1708 without taking the new material to full production, and with the dream of his scientific society still unrealised.[172] On the 28th March +1709 Johann Böttger reported to the King that he could make 'good white porcelain' and a few plain pieces of experimental Meissen porcelain were shown at the Leipzig Easter Fair in

[170] Two of Von Tschirnhaus's mirrors are illustrated in Hoffmann (1985), p. 210, and one is 158 centimetres in diameter. Von Tschirnhaus may well have been inspired to use concave mirrors for porcelain research by meeting the Milanese cleric Manfred Settala in the late +1670s. At this time Settala was using 'burning-glasses' for his own porcelain experiments. Weiss (1971), pp. 72–3.

[171] Kingery (1986), p. 152.

[172] The note, in Latin and in Böttger's hand, is illustrated in Hoffman (1985), p. 380. It is timed at 5 pm on 15 January +1708.



Fig. 167 Meissen white porcelain teapot, in imitation of Te-hua, *c.* +1716–25

+1710. The Saxon porcelains were made by adding small amounts of calcined alabaster and quartz to china clays, and needed temperatures in excess of 1,350°C to render them translucent.[173] Technologically Böttger porcelain was tougher, higher-fired and more heat-shock resistant even than contemporary Khang-Hsi period porcelain, which itself was of exceptional quality at this time. The Saxon material was improved over the next few years when both underglaze-blue decoration and overglaze enamelling were added to the factory's repertoire.

Early Meissen porcelain had a particular resistance to thermal shock, and one visitor to the works in Böttger's time described seeing a white-hot porcelain teapot withdrawn from the kiln and plunged into cold water without cracking.[174] The low-expansion characteristic of Böttger porcelain owed much to the very low levels of free quartz in the fired material. In terms of fired porcelain (as opposed to original mineralogy) this marked a continuation in Saxon porcelain of a trend to higher mullite and lower quartz levels that had been evident in Ching-te-chen bodies since

[173] One early Böttger porcelain recipe consisted of four parts of Snorr's kaolin, two parts of Colditz kaolin, 1.5 parts of white silica and 1.5 parts of alabaster. Raffo (1982), p. 84.

[174] This feat was replicated, successfully, at Massachusetts Institute of Technology in an experiment to check the anecdote. See Kingery & Vandiver (1986a), p. 173. The low free-quartz content of Meissen porcelain gave it exceptional resistance to thermal shock.

the +10th century (see Chart 10). In China, however, this trend was reversed in the later Chhing dynasty.[175]

With low-expansion bodies such as the Meissen material, the creation of glazes free from crazing presented formidable problems to the experimenters and it is interesting that one of the earliest Meissen glazes consisted of 100 parts silica, ten parts of Colditz clay and twenty parts of unrefined borax.[176] Both silica and borax impart low thermal expansion to glazes, and the recipe provides further evidence for the sophistication of the Meissen work. The boric oxide from borax was later replaced by calcia, another low-expansion oxide.

With the success of his Meissen venture, Augustus became a porcelain collector of manic enthusiasm, accumulating a vast collection of Chinese and Japanese wares. This compulsion in some ways negated the successful development of his own porcelain material. In fact one of Von Tschirnhaus's motives in his search to create porcelain may have been his alarm at the expenditure of hard cash on East Asian wares, and he once referred to China as 'the bleeding bowl of Saxony'.[177] Many objects from Augustus' collection became models for imitation at Meissen, and these included some fine Japanese vases and dishes, enamelled in the Kakiemon style, at that time the most prestigious of all East Asian wares.[178]

The glazes of Meissen porcelains were matured together with their bodies in high-temperature firings, in the East Asian manner, unlike the high-bisque, low-glost principles practised with soft-paste. After Böttger's death at the age of 37 in +1719, hastened by alcohol and overwork, the porcelain body-recipe was changed to a mixture of china clay, feldspar and a small amount of quartz, and the calcined alabaster was dropped (Table 144). However, the original calcareous recipes had already spread to Vienna, and were later used successfully at porcelain factories in Venice, Nymphenburg and Sèvres.[179]

FELDSPAR

The secret of these new feldspathic bodies too soon escaped from Augustus's fortress-factory. Later European, Scandinavian and Russian porcelain-makers

[175] See Wood (1999), p. 60, chart 1.

[176] Raffo (1982), p. 84.

[177] Honey (1934), p. 25. Honey wrote of Von Tschirnhaus's belief that 'the purchase abroad of so great a quantity of goods as the Chinese porcelain represented was a national loss to be averted', *ibid.*, p. 25. The origins and history of Augustus the Strong's collection of Chinese and Japanese porcelain is explored in Ströber (2001), where choice pieces are illustrated.

[178] Mallet in Ayers *et al.* (1990), writes: 'The quality and the accuracy of Meissen reproductions of Japanese Kakiemon style wares were notably fine – as seen in the Rijksmuseum collection, Amsterdam, where Japanese originals and Meissen imitations are displayed together. Much of this quality was due to the Meissen factory's sure control of overglaze enamel technology.' As Antoine d'Albis (1999), p. 35, notes: 'between 1725 and 1735, the Saxons learned how to decorate their porcelain with a range of about fifty colours that were as clear, bright, lively and accurate as the notes on a well-tuned instrument.'

[179] A key figure in the spread of porcelain technology in Europe was Joseph Jakob Ringler (+1730–1804), originally of the Vienna factory, founded in +1719. Vienna was the first hard-paste works to be set up after Meissen, using Meissen expertise, Saxon clay, Meissen arcanists and a Meissen-style kiln. See Weiss (1971), p. 83, for details of the 21 continental European porcelain factories that Ringler had some part in founding.

Table 144 *Böttger and later Meissen feldspathic porcelain compared with Khang-Hsi Ching-te-chen wares*

	C.	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	rest	Total
Böttger porcelain	+1715	61.0	33.0	-.-	-.-	4.8	-.-	0.1	0.2	-.-	0.9	100.0
Meissen porcelain	+1731	59.0	35.0	-.-	-.-	0.3	-.-	4.0	0.8	-.-	0.9	100.0
Khang-Hsi porcelain	E +18th	66.7	26.25	-.-	0.9	1.25	0.33	2.65	2.15	-.-		100.2
Khang-Hsi porcelain	E +18th	65.0	26.7	0.13	1.1	1.6	0.1	3.1	2.6	0.07		100.4

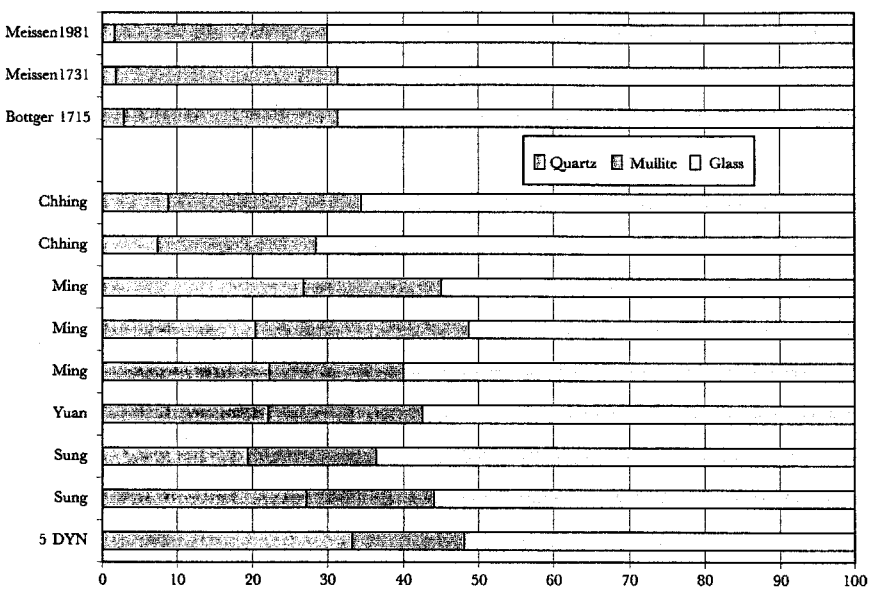


Chart 10 Quartz, mullite and glass contents of fired Meissen porcelains, compared with Ching-te-chen porcelains (+10th to +18th centuries)

tended to adopt the more reliable feldspar-fluxed compositions, particularly at new works in Berlin, Copenhagen and St Petersburg. Feldspar-fluxed porcelains of the post-Böttger type remain the standard hard-paste recipes at most continental European factories today, with their high firing temperatures, mostly in excess of 1,350°C, surviving from the Meissen experiments. The use of both pure kaolins and feldspars as body-fluxes in porcelain, however, may well have been anticipated in

China in the +6th to +7th centuries, at the early Hsing ware 邢窯 kilns, in Nei-chhiu 內丘 county in Hopei province (see pp. 155–7).[180]

THE SIGNIFICANCE OF THE MEISSEN WORK

In retrospect we can see that Von Tschirnhaus and Böttger were able to avoid the mixtures of glass, sand and clay that had limited 'Western' experiments in making copies of East Asian porcelains since the +11th century, by basing their new porcelains on refractory white-firing clays.[181] This approach may well have come from Von Tschirnhaus's fundamental work with the fusion of raw materials in his solar furnaces. As David Kingery has stressed, the temperatures involved in these experiments were also unprecedented in Europe at the time and the development of the Meissen kiln should be seen as important to the success of the project as the porcelain body itself.[182] The kiln was of a cross-draft type about three metres long inside and probably derived from Saxon salt-glaze manufacture, but with three fireboxes rather than the usual one.[183] With its high-clay nature, its elevated firing temperature and its calcareous flux, early Meissen porcelain, and its early offshoot, Vienna porcelain, were much closer in their compositions to the long-abandoned porcelains of north China, such as Ting ware 定窯, than to the early +18th-century wares of Ching-te-chen, although such parallels with the long-extinct northern porcelains were entirely coincidental (Table 145).

CONTINENTAL SOFT-PASTES

Despite the spread of hard-paste porcelain in the +18th century, a few high-quality soft-pastes continued to be made in continental Europe. Sèvres *pâté tendre*, for example, was made throughout the later +18th century, and was not finally abandoned until +1805. Another significant soft-paste material was developed in +1743 at the Italian Capodimonte porcelain factory in the grounds of the Royal Palace, on a hill overlooking the city of Naples. Capodimonte porcelain was a highly siliceous body, closely akin to a refined Islamic stone-paste, and with an alkaline glaze to match. The main productions of the Naples factory were figurines and vases for display, probably because the body was unsuitable for tableware through its poor resistance to thermal shock. The most spectacular use for this very pure and warm-toned

[180] Chen Yaocheng *et al.* (1989a), pp. 221–8.

[181] White-firing and refractory kaolinitic clays were not entirely new to European fine ceramics. They had been used both by Bernard Palissy in the +16th century, and by the makers of the elaborate +16th-century French Sainte-Porchaire wares, decorated with intricate veneered patterns in contrasting clays. However, in both cases biscuit-firings of 1,000–1,100°C, and glaze firings nearer to 1,000°C, had probably been used. See Tite (1996), pp. 103–4.

[182] Kingery (1986), pp. 168–70.

[183] A version of the first Meissen kiln was soon built at Vienna, and a Viennese version is illustrated in the *Atlas* of Brongniart's +1844 treatise on ceramics (fig. 3, pl. XL). This can be compared with a drawing of the Meissen kiln in operation in Hoffman (1985), p. 407.

Table 145 *Analyses of Ting ware bodies and Böttger and Vienna porcelains*

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	Total
Ting ware body 1, Thang dynasty[a]	59.8	34.5	0.4	0.7	1.1	0.9	1.25	0.7	0.03	99.4
Ting ware body 2, Five Dynasties	61.2	32.9	0.6	0.6	3.4	0.9	1.25	0.1	0.02	101.0
Ting ware body 3, Northern Sung dynasty	62.0	31.0	0.5	0.9	2.2	1.1	1.0	0.75	0.04	99.5
Ting ware body 4, Chin dynasty	59.25	32.7	0.75	0.7	0.8	1.1	1.7	0.3	0.01	97.3
Böttger porcelain, +1712[b]	61.0	33.0	-.-	-.-	4.8	-.-	0.1	0.2 (rest 0.9)		98.9
Vienna porcelain, +19th century[c]	61.5	31.6	-.-	0.8	1.8	1.4	2.2	(rest 0.7)		99.3

[a] Ting ware analyses, Li Guozhen & Guo Yanyi (1986), p. 136, table 1.
[b] Schulle & Ullrich (1982), p. 45, table 4.
[c] Brongniart (1844), vol. 2, p. 386.

material was to panel a complete 'porcelain room' in the nearby Royal palace between +1757 and +1759, where some 3,000 interlocking porcelain panels created a triumph of Rococo design with a strong Chinoiserie theme. The Capodimonte body recipes had parallels at the Doccia, Cozzi and Le Nove factories, and seem to have been of a peculiarly Italian type.[184]

The Capodimonte factory was moved (moulds, materials and manpower) to Madrid in +1759 when Charles III, Bourbon king of Naples, became the King of Spain. Here the works became known as Buen Retiro, after the nearby royal palace, where another 'porcelain room' was eventually constructed. The Madrid factory was blown up by the Duke of Wellington in +1808 after it had become a French garrison during the peninsula war.

British Porcelain

The association of +18th-century continental European porcelain manufacture with city-states, powerful principalities, and royal factories meant that fortunes were spent on making prestige objects, often with scant regard to cost.[185] Another characteristic of the continental work was a tendency to make either quartz-based

[184] Freestone (2000), p. 21, referring to some unpublished British Museum analyses.
[185] Weiss (1971), p. 79, lists 45 European royal patrons of porcelain in the +18th and early +19th centuries, 21 of whom actually founded factories. Weiss quotes the words of Duke Carl Eugen in April +1758 on the founding of the Ludwigsburg factory, when the Duke described porcelain as: 'the indispensable accompaniment of splendour and magnificence.' Weiss (1971), p. 77.

soft-pastes or clay-based hard-pastes. By contrast, a series of modest (and often short-lived) private ventures and a bewildering range of body-recipes often produced within the same factories, mark the story of pioneer British porcelain-making. Some of these bodies used oxides of elements such as lead, barium and phosphorous that had precedents neither in continental porcelain practice, nor in the East Asian originals. Besides these curiosities, the history of British porcelain-making also includes some of the closest matches to the true Ching-te-chen material made in the West, particularly from the work of John Dwight at Fulham, and of William Cookworthy at Plymouth.

JOHN DWIGHT'S PORCELAIN

Amongst the mass of salt-glazed stoneware excavated from the site of the Fulham Pottery in London in the +1970s were a number of collapsed wares and test pieces, some decorated with cobalt-blue, associated with the porcelain experiments made at Fulham by the scholar, alchemist and potter John Dwight (+1637–1703) in the late +17th century. These have been related to Dwight's own patent of +1672 that describes the: 'manufacture of transparent earthenware commonly known by the name of Porcelane or China & Persian ware.' Dwight's white bodies (thought to date from the early +1670s) appear to have been mixtures of light-firing ball clays from Dorset, powdered quartz sand, and a potassic glass frit that contained saltpetre and tartar (an impure form of potassium hydrogen tartrate). The glaze was a thin, hard, potassium-rich composition that matured at the same temperature as the body.[186]

Three qualities in particular distinguished these sherds from the great mass of glass-clay-quartz compositions used for copying East Asian porcelain in the Near East and Europe over the previous five centuries. These are the temperatures at which the Fulham wares were fired (in excess of 1,250°C in one case), the hard glazes matured with the bodies, and the closeness of their compositions to true porcelains of the more siliceous East Asian types. These distinctive features seem to have been managed by raising both the silica-rich and clay-rich elements of the recipes against the glassy fraction. This took the compositions into the region of East Asian quartz-mica porcelains, but without any substantial use of mica or feldspar as body-fluxes. The hard potassic glazes are thought to have been either deliberate vapour glazes (like salt-glaze) or perhaps natural effects caused by some efflorescence of soluble potassium salts from the bodies during drying. Nonetheless, problems with designing suitable glazes, and the expense and difficulty of the high-temperature firings needed to mature the materials, seem to have led to the demise of Dwight's off-white 'porcelane'. By contrast Dwight's imitations of Rhenish salt-glazed stoneware were a notable success, and his pioneering versions of I-hsing 宜興 red stonewares, using red Staffordshire clay, were successfully developed by

[186] For a full discussion of Dwight's experiments, see Tite *et al.* (1986), and Green (1999), pp. 64–108.



Fig. 168 Chinese Te-hua export porcelain mug and a pair of John Dwight 'gorges', *c.* +1680–95

the Elers brothers at Bradwell Wood, near Stoke-on-Trent, in the last decade of the +17th century.[187] The use of ball clay in Dwight's 'porcelanes' seems to disqualify them as true imitations of the Chinese wares, as the titanium dioxide levels in the clays caused slight greyness and opacity in the fired material.[188] Even so, these unsuccessful experiments to make translucent white porcelain in the early +1670s did help towards the development of a fine near-white salt-glaze body at the Fulham factory in the +1690s.

China Clay

The lack of suitable china clays appears to have inhibited most early experiments with porcelain-making in England, although this was ingeniously solved by some factories' importing fine kaolins from Cherokee territory in colonial North America, particularly from the Blue Ridge deposits of North Carolina. These American clays have been tentatively identified with the *unaker* mentioned in the first Bow patent of +1745, and were perhaps used too in the mysterious 'A-marked' porcelains of the late +1740s. Bodies using these clays have been described as 'clay-rich glassy

[187] The former silversmiths from Amsterdam used making methods with their red stonewares, such as sprigging with metal moulds, lathe-turning and slip-casting that later helped to transform the Staffordshire industry. They worked in Staffordshire from at least +1691 to +1700, when they were declared bankrupt. See Elliot (1998), pp. 18–21, 38. The close compositional similarities between I-hsing stoneware clays and North Staffordshire 'Etruria Marl' are noted in Wood (1999), p. 148, table 57. However, the lathe-turned finishes used by both Dwight and the Elers brothers were quite different from the construction with thin slabs, followed by moderate burnishing, used for the I-hsing originals (see pp. 450–3).

[188] Iron-titanium compounds in secondary clays are often in the form of leucoxene, found 'as a thin deposit between kaolinite plates and so contributes to the general darkening of the wares.' Lawrence & West (1982), p. 39.

soft-pastes', and represent a particularly English version of the clay-quartz-glass trinity.[189]

COOKWORTHY PORCELAIN

With hindsight we can see that Cornwall and Devon would have been closer and better sources for china clays than North Carolina, as these counties have some of the finest porcelain-clay deposits in the world. However it was not until the Plymouth Quaker and pharmacist William Cookworthy (+1705–80) tested rocks and clays from near St Austell in the +1740s that their potentials for porcelain-making were realised. Cookworthy was informed in his work by the letters of Père d'Entrecolles, published in J. B. Du Halde's *Description Geographique de l'Empire de la Chine*, which came out between +1725 and +1741.[190] He also seems to have been prompted to prospect for the porcelain materials by an unnamed visitor in +1743, thought by some to have been the American potter Andrew Duché. Cookworthy records the meeting:[191]

> Plymouth, 30th of the 5th Mo. 1745.
> I had lately with me the person who has discovered China Earth. He had with him several samples of the china ware, which I think are equal to the Asiatic. It was found at the back of Virginia where he was in quest of mines; and having read Du Halde, he discovered both the Petunse and Caulin. He is gone for a cargo of it; having bought, from the Indians, the whole country where it rises. They can import it for £13 per ton and by that means afford their china as cheap as common stoneware; but they intend to go about 30 per cent under the company.

In fact porcelain-making in Europe can be conveniently divided into pre- and post-d'Entrecolles, with most continental European porcelain recipes pre-dating the *Letters* and most British porcelains developed after their publication. This fact may account for much of the variety, and perhaps too some of the eccentricity, of British porcelain compositions.

Cookworthy's patent for using these materials is dated to +1768, when *The New Invented Plymouth Porcelain Company* was established, although his original experiments with the West Country rocks probably began some two decades earlier. The importance of Cookworthy's work lies in the way that he correctly identified close relations of Ching-te-chen porcelain stones and china clays near St Austell and then

[189] Freestone (1996), pp. 80–2; Freestone (1999), p. 7.

[190] The first French edition containing the letters came out in +1735; the English edition in +1736; with another edition in 1738 (vol. 1) and +1741 (vol. 2). See Du Halde (1735), vol. 2, pp. 171–204, Du Halde (1736), vol. 2, pp. 309–55.

[191] First quoted in Owen (1873), p. 7ff. It is thought that 'the company' referred to is the East India Company. Andrew Duché has been credited with making true hard-paste porcelain in America as early as +1742, although no undisputed examples of his work survive. His later career appears to have been as a 'merchant and prosperous land owner' rather than as a potter, and he died in Philadelphia in +1778. See Mackenna (1946) for a full account of Duché's life and influence. However, this passage is still contentious. For example, Watney (1973), p. 16, argues that the china ware described may have been made in England from American materials, and not in colonial America.



Fig. 169 Cookworthy mug dated 14 March +1768

processed and fired these materials to create true hard-paste porcelains of the East Asian type, mostly decorated with underglaze-cobalt-blue painting.[192]

A less-appreciated aspect of Cookworthy's work was the first systematic use of reduction-firing for glazed ware in England, using an updraught wood-fired kiln, with the reducing atmosphere perhaps made necessary by the type of underglaze-cobalt pigment used.[193] Cookworthy's glazes followed the Ching-te-chen practices described by Père d'Entrecolles, although his ash-to-lime ratios were higher than those used at Ching-te-chen. From the few analyses of Cookworthy

[192] Cookworthy traded in cobalt, which he brought from Silesia (now Germany), probably from the celebrated Schneeburg mines. Silesian cobalt was sold in the form of smalt, the intensely coloured potassium silicate glass that resulted from German refining methods (see p. 687). Cookworthy sold the cobalt to the Bristol blue glass trade. Weedon (1984), p. 23. A single, rather experimental example of cobalt-blue painting on the early Cookworthy mug, illustrated in Fig. 169 gave an iron-cobalt-nickel mixture, characteristic of German cobalt (Mike Cowell, pers. comm. 2002). However, smalt may have been too highly fluxed a material for the successful decoration of hard-paste porcelain, and it is possible that Cookworthy was later able to use a local cobalt ore from a mine in Truro. This was discovered by Francis Beauchamp, for which he received a Society of Arts award of £50 in +1755. Royal Society of Arts manuscripts, vol. 2 (1754–8).

[193] A detailed scale drawing of the main Plymouth porcelain kiln was made in +1770 by Richard Champion, who later bought Cookworthy's patents, and continued the production of English hard-paste porcelain at Bristol from +1772 to +1783 (see Owen (1873), p. 19, pl. ii). The Plymouth kiln is a tall round-sectioned updraught design with the firing-chamber six feet across inside, and seven foot high, with a second chamber, apparently for biscuit-ware, set above the high-temperature compartment.

Table 146 *+16th-century Khang-Hsi and Cookworthy porcelains (Plymouth and Bristol) compared*[a]

	+C	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	Total
Ching-te-chen (body)	16	68.4	24.6	0.1	1.1	0.8	0.2	3.6	1.1	0.07	100.0
Ching-te-chen (body)	16	69.5	22.9	0.1	1.1	0.4	0.2	3.9	1.1	0.08	99.3
Khang-Hsi (body) (C14)	18	66.7	26.25	-.-	0.9	1.25	0.33	2.65	2.15	-.-	100.2
Khang-Hsi (body) (C17)	18	65.0	26.7	0.13	1.1	1.6	0.1	3.1	2.6	0.07	100.4
Khang-Hsi glaze (C14)	18	70.8	14.9	-.-	1.0	5.5	0.75	3.2	2.6	0.13	98.9
Khang-Hsi glaze (C17)	18	67.9	15.7	-.-	1.2	7.1	1.1	4.1	2.1	-.-	99.2
Plymouth (body)	18	72.3	23.1	-.-	0.4	0.3	0.3	3.0	0.7	-.-	100.1
Bristol (body)	18	70.8	24.0	-.-	0.5	0.5	0.5	3.0	0.7	-.-	100.0
Plymouth (glaze)	18	78.1	11.8	-.-	0.6	2.7	1.8	4.0	1.0	-.-	100.0
Bristol (glaze)	18	71.1	16.8	-.-	0.5	3.6	2.3	4.2	1.5	-.-	100.0
St Austell China clay Rock (fired)[b]		73.7	22.8	0.1	0.07	0.2	0.1	2.8	0.1		99.9

[a] Unpublished analyses from the Research Laboratory for Archaeology and the History of Art, Oxford. Tite *et al.* (1991), pp. 8–9, tables 1 and 2.
[b] From Exley (1959), p. 218, table VII.

porcelain that have been made, his porcelain material appears rather nearer to +16th-century Ching-te-chen wares than to the early +18th-century materials described by Père d'Entrecolles (Table 146). Nonetheless, the porcelain was still very similar to a mainstream Ching-te-chen type.

The dominance of potassium over sodium oxides in Cookworthy's porcelains suggests that the bodies were either mixtures of Cornish stone of the sericitised Hard White type with refined china clay, or were made entirely from crushed and processed china clay rock.[194] Cookworthy mentions both one- and two-material body-recipes in the undated summary of his porcelain practice (probably written at the time of his first patent in +1768) so both approaches seem likely. Indeed

[194] A mineralogical analysis of Hard White stone, from the Goonvean & Rostowrack China Clay Co. Ltd., St Austell, Cornwall (Great Wheal Prosper Quarry) gives: Quartz 30%; Soda feldspar 13%; Potash feldspar 15%; Muscovite mica 20%; and Kaolinite 10%. (Supplied to NW in +1991.) This can be compared with a porcelain stone used by the imperial kilns at Ching-te-chen in the +1880s: Quartz 42.4%; Feldspars (mainly albite) 31.6%; and Mica 26%; from Vogt (1900), p. 551.

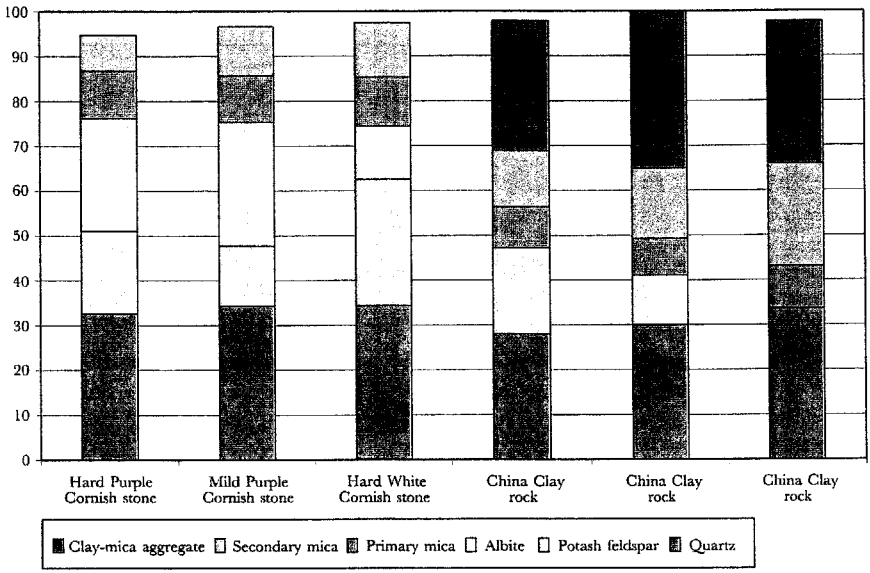


Chart 11 Progressive changes in mineralogy from Hard Purple Cornish stone to fully altered China clay rock

the use of processed china clay rock would have created a material particularly rich in fine secondary potassium mica, and low in feldspars. This made some Cookworthy porcelains not only true hard-paste materials, but also genuine East Asian-style porcelains of the quartz-hydromica style (see Table 146 and Chart 11).[195]

Cookworthy wrote of his glazes:[196]

The best, I have tried, are those said to be used by the Chinese, viz. Lime and fern ashes, prepared as follows. The lime is to be slaked by water, and sifted. One part of this, by measure, is to be mixed with twice its quantity of fern-ashes, and calcined together in an iron pot; the fire to be raised till the matter is red hot. It should not melt; and for that reason, should be kept continually stirred. When it sinks in the pot, and grows of a light ash colour, 'tis done. It, then, must be levigated in the Potter's mill, to perfect smoothness. It may be used in the proportion of one part to ten [to glaze stone], and so on to fifteen or twenty of the stone, as shall be found necessary.

Cookworthy used for his glazing 'stones . . . with green spots from Tregonnin hill'. This represented another attempt to follow d'Entrecolles account, where the Jesuit wrote:[197]

[195] Wood & Cowell (2002), p. 329, table 1.
[196] Appendix V in Harrison & Compton (1854), p. 204.
[197] D'Entrecolles in Du Halde (1736), p. 316.

Table 147 *Glazes used on Plymouth and Ching-te-chen porcelains*

	C.	SiO_2	Al_2O_3	TiO_2	FeO	CaO	MgO	K_2O	Na_2O	(R_2O+RO)	P_2O_5	MnO	Total
Khang-Hsi glaze	+18	70.8	14.9	-.-	1.0	5.5	0.75	3.2	2.6	(13.05)		0.13	98.9
Khang-Hsi glaze	+18	67.9	15.7	-.-	1.2	7.1	1.1	4.1	2.1	(15.6)		-.-	99.2
Plymouth glaze	+18	78.1	11.8	-.-	0.6	2.7	1.8	4.0	1.0	(10.1)		-.-	100.0
Bristol glaze	+18	71.1	16.8	-.-	0.5	3.6	2.3	4.2	1.5	(12.1)		-.-	100.0
Fern ash (fully washed)[a]		40.4	12.0	n.t.	0.7	20.6	10.9	2.35	n.t.		4.4	n.t.	91.35

[a] Leach (1940), p. 162.

Tho' the kind of Stone which makes *Pe tun tse* may be used to get the Oil [i.e. glaze] also, yet chose a whiter sort, the Spots of which are of a deeper Green.

However, Cookworthy's preparation of the glaze-flux represents a slight change to Ching-te-chen practice. At Ching-te-chen an initial burning of limestone at a high temperature produced quicklime (CaO) which soon hydrated to calcium hydroxide ($Ca(OH)_2$). Further burnings at a lower temperature converted the material to calcium carbonate ($CaCO_3$).[198] Whether Cookworthy's method also resulted in calcium carbonate is hard to say, but the resulting 'glaze ash' probably had a far higher ratio of ash to lime than the Ching-te-chen original. This high proportion of fern ash may partly account for the elevated magnesia figures in the Plymouth glazes, fern ash having a fair content of magnesia (see Table 147). However, another source of magnesium oxide may well have been the '*magnesia-alba*' mentioned as a glaze material in Cookworthy's original patent.[199] The relatively low flux totals in Cookworthy's glazes suggest that the firing temperatures used for Plymouth porcelain were in excess of 1,300°C. Indeed the compositions of Cookworthy's glazes often seem too hard for the porcelain bodies they are matched with, and this may partly account for the high failure rates associated with this factory (see R_2O+RO column in Table 147).

Cookworthy sometimes applied his glazes to the raw porcelains in the Ching-te-chen manner, but noted that once the raw-glazed wares were dry it was difficult to check the glaze thickness because glaze and clay were so similar:[200]

Large vessels may be dipped raw, as the Chinese are said to do it. But the proper thickness of the glaze is not so easily distinguished this way, as when the ware is biscuited . . . 'tis hardly possible to determine the limits of either; a thing very easy to be done, when the body is hardened by biscuiting.

Perhaps because of a shortage of skilled potters in Plymouth, Cookworthy's factory was moved to Bristol in +1770, where it was run by one of his original backers,

[198] Vogt (1900), p. 566.
[199] Cookworthy's patent of +1768 is reproduced in full in Mackenna (1946), pp. 34–6. Magnesia-alba (lit. 'white magnesia') is the old name for hydrated magnesium carbonate.
[200] Appendix V in Harrison and Compton (1854), p. 204.

Richard Champion. Champion bought Cookworthy's patents in +1773, but the business was dogged by troubles. A group of Staffordshire potters (led by Josiah Wedgwood) successfully challenged renewal of Champion's hard-paste patents in +1775, winning the rights to use Cornish stone and Cornish china clay in their own opaque wares.[201] In +1781 Champion's worsening financial state (plus legal bills) forced him to sell his patents outright to eight North Staffordshire potters, leaving them free to exploit these fine West Country materials in translucent whitewares, as well as in true hard-paste porcelains.[202] The Cornish materials were subsequently used in Stoke-on-Trent to improve white earthenware bodies, to make true hard-paste porcelains of the Cookworthy type, and to develop superior bone china recipes. Nonetheless manufacture of hard-paste in North Staffordshire, at works such as New Hall, was short-lived, and declined in the second decade of the +19th century with the introduction of improved bone china bodies.

Bone China

Not all English interpretations of Père d'Entrecolles letters were as accurate and authentic as Cookworthy's, as seen in the strange case of phosphatic porcelains and bone china. In his +1712 letter Père d'Entrecolles recorded the Chinese description of the 'bones and flesh' of porcelain (Chinese kaolin and porcelain stone respectively, see p. 220).[203] Whether or not this entirely metaphorical account led to experiments in England with burned animal bone (calcium phosphate) as a potential porcelain ingredient is debatable, though not wholly implausible, given the rather random and alchemical nature of much British porcelain research. But however prompted, bone ash worked surprisingly well as a ceramic raw material. It served both as a calcareous body-flux and as a whitening agent in some mid +18th-century porcelains. Bone ash helped to improve the apparent purity of porcelains that might otherwise have fired too grey, from the use of ball clay in their bodies.

Bone-ash porcelain was formed by combining calcined bone with glass and clay. Thus in the case of bone-ash porcelain, and its later relative bone china, the 'flesh' element was provided by calcined animal bone.[204] One of the earliest English porcelain factories to experiment with the material was at Stratford-le-Bow in Essex in

[201] The men of Stoke were determined to win access to the Cornish materials, leading Cookworthy to write in +1775: 'Poor Richard is like a lamb facing the lions. I pray that the lord will give him courage to endure.' Quoted in Penderill-Church (1972), p. 75.

[202] Josiah Wedgwood was not among the eight in this second assault on Champion's patents. He had found his own supplies of Cornish stone and china clay from a field next to Cookworthy's.

[203] 'A rich merchant told me that several years ago some Europeans purchased some petunse, which they took back to their own country in order to make some porcelain, but not having taken any kaolin, their efforts failed (as they acknowledged later). Upon which the Chinese merchant told me, laughing, "They wanted to have a body in which the flesh would be supported without bones".' Tichane (1983), p. 67, translation of Père d'Entrecolles letter of +1712.

[204] Bow, the first factory in England to make bone-ash porcelain, was active between +1747 and +1774. Early Bow ware contains 25% by weight of bone ash, cf. Adams & Redstone (1991), p. 1. When china clay and china stone became freely available at the end of the +18th century, they were used together with quartz sand and bone ash to make what is known as bone china, Tite & Bimson (1991), pp. 3–4, 24.

+1749, when 'virgin earth' (bone ash) supplied nearly half the body recipe, as detailed in Thomas Frye's patent of the same year.[205]

Early bone-ash porcelains (such as Chelsea, Lowestoft, Derby and Isleworth) also relied on bone ash's whitening effect on less than pure clays.[206] The transfer of Champion's patents to North Staffordshire allowed Cornish porcelain stone and Cornish china clay to be used in 'second generation' bone china bodies. Josiah Spode I's recipe of +1794 and Josiah Spode II's recipe of +1800, in particular, used the materials to great advantage, and fine bone china soon became Stoke-on-Trent's main translucent whiteware production.[207]

Bone china still serves this role today, with a typical modern recipe consisting of 50% bone ash, 25% china clay and 25% Hard White Cornish stone.[208] Present-day bone china is given an initial firing to about 1,250°C, with flatwares such as plates entirely supported in the kiln. The glaze firing is usually carried out at about 1,060°C, using a leadless borosilicate glaze, although high-lead glazes were used on the material from the mid +18th century until the +1980s. Strict oxidation is necessary in both firings to ensure warm tones in the wares, which show a warm whiteness and translucency superior to the best hard-paste porcelains, although with the disadvantage of a softer glaze.

Soapstone Porcelain

Another unusual +18th-century porcelain may also have owed its existence to a misunderstanding of early missionary accounts of porcelain. This was soapstone porcelain, made from hydrated magnesium silicate rocks such as steatite and talc.

The mineral was identified in England with soapstone, of which supplies from the Lizard peninsula in Cornwall were added to quartz sand, flint and alkali-lime glass to make a highly successful product.[209] Glazes for both bone-ash porcelain and soapstone porcelain were of the lead-alkali type.[210]

These bodies may have been stimulated by the letters of Père d'Entrecolles (see p. 228) in which a mineral called *hoa che* or 'slippery stone' was mentioned as a fine porcelain ingredient at Ching-te-chen.[211] We now know that the *hoa che (hua-shih* 滑石)

[205] The term 'virgin earth' has been traced by Watney to mid +18th-century chemical texts, where it refers, among other things, to calcined, ground and washed animal bones. Watney (1973), pp. 12 and 125.

[206] Freestone (2000), pp. 24–5.

[207] Spode's basic recipe was six parts bone ash, four parts Cornish stone, and three-and-a-half parts china clay. However, as Ian Freestone notes, bone china and the earlier bone-ash porcelains were rather different materials: 'Both are phosphatic but, whereas bone-ash porcelain was based on bone ash, ball clay and glass, bone china, which was introduced from about 1800, comprised bone ash, china clay and china stone.' Freestone (1999), p. 6.

[208] Singer & Singer (1963), p. 109. See also pp. 457–64 for a detailed discussion of bone china's technical properties.

[209] Soapstone porcelain was first made at Bristol by +1750 and subsequently at Worcester, Vauhall, Derby and Liverpool, Tite & Bimson (1991), pp. 4, 24.

[210] *Ibid.*, pp. 24–5.

[211] We have seen that a town called Hua-shih (*hoa che*) was mentioned in the account of another missionary, de Mandelslo, see p. 745.



Fig. 170 Bow porcelain vase in imitation of Chinese *famille rose c.* +1750

mentioned in early Western accounts was actually a highly micaceous kaolin, but 'slippery' talc-like stones were tested in England in the mid +18th century. William Cookworthy has been credited with suggesting this material as a potential porcelain ingredient, and he refers to Père d'Entrecolles' '*Wha She or Soapy Rock*' in a letter of his own memoir on porcelain-making.[212] Rather against the odds, soapstone worked well in porcelain bodies, and factories such as Bristol, Worcester, Caughley, Vauxhall, Swansea and Liverpool all made successful soapstone porcelains in the later +18th century. Nonetheless, these novel recipes did not survive long into the +19th century, when they were superseded by improved bone china recipes of the types developed by the Josiahs Spode.

WEDGWOOD'S JASPER WARE

Perhaps the most remarkable of all +18th-century English porcelains owed little to East Asian models. This was Jasper ware, designed by the great Staffordshire potter, Josiah Wedgwood (+1730–95) in the +1770s. Josiah Wedgwood was the thirteenth son of Thomas Wedgwood and began work as a potter at the age of fourteen, at his father's Churchyard Works in Burslem. This country workshop in North Staffordshire was operating at a time when the craft was on the verge of industrialisation, following innovations such as salt-glazing, fine-sprigging, lathe-turning and slip-casting. The latter three processes were apparently brought to the district by the Elers brothers in the late +17th century (see p. 757).[213]

Wedgwood established himself as a potter on his own account in Burslem in +1759, and became a tireless experimenter with new bodies, glazes and manufacturing methods.[214] He also studied the measurement of high temperatures by the shrinkage of ceramic 'coupons', for which work he was made a Fellow of the Royal Society in +1783.[215] Wedgwood also pioneered canal transport and steam power for the Potteries and played a leading part in breaking Champion's patents. Wedgwood desired access to the Cornish clays and stones, both to improve the North Staffordshire industry, and to further his own researches.

Wedgwood's interests in ceramic materials and processes were wide ranging, and included Chinese porcelain. He had read Du Halde and the French traveller and geologist Faujas de St Fond. In +1773 Wedgwood experimented with porcelain raw materials, collected in China by the naturalist John Bradley Blake, with whom he corresponded, until Blake's death in +1773 cut short this project.[216] Nonetheless, despite abandoning his researches into Chinese porcelain, Wedgwood may well have used Père d'Entrecolles accounts of Ching-te-chen workshop organisation to

[212] Harrison & Compton, quoting Cookworthy (1854), p. 199.
[213] Elliot (1998), pp. 17–21.
[214] Wedgwood referred to these systematic and far-ranging experiments with ceramic materials as his 'Tinkerings'. Reilly (1994), p. 82.
[215] Wedgwood (1782). See also Rostoker & Rostoker (1989).
[216] Reilly (1994), p. 72.

introduce division of labour to his Etruria works.[217] In the end Wedgwood's real interests proved to be neo-classical rather than oriental, and his particular contribution to English porcelain-making was to design a strongly coloured porcelain body in the +1770s that he called Jasper ware.

The basis of Wedgwood's Jasper ware was the newly discovered element barium, introduced into the body-recipe in the form of barium sulphate. The 'barytes' was found near to Stoke-on-Trent, in mines between Matlock and Middleton in Derbyshire, some 55 kilometres to the east of Stoke-on-Trent. Wedgwood had the material secretly transported to Liverpool or London, and then, more openly, back to the Potteries, to confuse his competitors.[218] The unglazed Jasper porcelain was coloured variously with oxides of cobalt, manganese, chrome and iron, to give blue, pink, green and yellow porcelain biscuit-wares respectively. These were usually made into neo-classical forms and plaques, and often decorated with white sprigs of the uncoloured Jasper material. This was the first significant use of barium in world ceramics since the 'Chinese Blue' and 'Chinese Purple' pigments and glazes of the Warring States period (see pp. 610–14). There was even some interest in China in Wedgwood's Jasper ware, and a few versions were made at the Ching-te-chen imperial kilns towards the end of the +18th century, but using conventional porcelain materials (see Fig. 171).

With its origins in fundamental materials research, rather than in simple observation and guesswork, Jasper ware should perhaps be classed with early Meissen porcelain and with Von Tschirnhaus's late +17th-century experiments. Before he was able to use Cornish stone and Cornish china clay in his Jasper body, Josiah Wedgwood had imported a small amount (about five tonnes) of china clay from North Carolina, and even shipped some china clay from New South Wales in +1789.[219] Wedgwood eventually secured his own supplies of Cornish stone and kaolin from the Carloggas estate in Cornwall.[220]

ENGLISH KILNS

Information for the design of English kilns is limited, but from what we know none of the kilns resembled in either appearance or function Chinese dragon or

[217] In the first 50 years of Josiah Wedgwood's life the value of the North Staffordshire potteries' output increased fivefold, with Wedgwood making a significant contribution to the industry's growth. As Lord points out: 'For a long time he combined the functions of employer, merchant and foreman, and he represents the intermediate stage of paternal employer between the gild [guild] master and the pure capitalist.' Lord (1923), p. 143.

[218] Reilly (1994), pp. 78, 90.

[219] On 15 December +1777 Wedgwood wrote to Thomas Bentley that he had considered making the use of 'Cherokee clay' a selling point for his Jasper ware. However, as other commentators have noted, the sole amount of North Carolina kaolin imported by Wedgwood in +1768 (*c.* five tonnes) would not have lasted long, and any amounts present in +1777 Jasper bodies must have been minute. See Reilly (1994), pp. 89–90.

[220] Watney (1973), pp. 129–30.



Fig. 171 Pair of Chinese porcelain vases imitating Wedgwood, late 18th century

egg-shaped porcelain kilns (see pp. 347–72).[221] The successful firing of all types of porcelain-like ceramics required huge quantities of fuel.[222] Unlike Ching-te-chen, both wood and coal were used at several factories, and it was customary of site factories to take advantage of cheap coal. However, England's first true hard-paste porcelain, made and fired in the Chinese manner by William Cookworthy at Plymouth and Bristol, needed wood firing as coal stained the wares with sulphur.[223] Cookworthy wrote in his undated memoir on porcelain-making:[224]

[221] Young (1999b), illustrates a multi-flued updraught sagger kiln, a biscuit kiln, a glaze kiln and an enamelling kiln from Worcester; the kiln used by William Cookworthy; and sketches of a kiln at Derby. These appear to be the only extant, contemporary, illustrations of English +18th- to early+19th-century kilns, and archaeology has not augmented information to any great extent, though Young includes several contemporary verbal descriptions of kilns. It is extraordinary to think that less record was left of +18th-century English kilns than –3rd-century Chinese kilns.

[222] In the +1790s, Worcester porcelains went through eight kilns several times, the entire cycle lasting nearly 200 hours. New Hall required between ten and twelve tons of fuel to fire one ton of finished wares, Young (1999b), p. 1.

[223] Young (1999b), pp. 2–7.

[224] Harrison & Compton (1854), p. 206.

The only furnace or kiln we have used with any degree of success is that used by the potters who make brown stone. It is called the 36 hole kiln. Wood is the fuel used in it. They burn billets before and under it, where there is an oven or arch pierced by 36 holes, through which the flame ascends into the chamber which contains the ware, and goes out at as many holes of the same dimension in the crown . . .'.

Cookworthy stresses the superiority of this design over the kilns used in the 'north of England' that burned coal in side fireboxes. The French traveller, Gabriel Jars, described such kilns near Stoke-on-Trent in +1765, when they were used for white salt-glazed stoneware near Newcaste-under-Lyme. The kilns had 30 holes in their crowns and eight coal-burning fireboxes set into their walls. After 44 hours firing four or five hours were spent spooning salt into the incandescent kilns to vapour-glaze the wares.[225] However, the lack of coal in Cornwall, and the need to fire with wood, added greatly to the expense of making Plymouth porcelain.

An Audit of Contemporary Porcelains and White-Glazed Earthenwares

The Jasper wares of the Wedgwood factory no longer contain barium, and soapstone porcelains are now extinct in Britain. In Scandinavia, Russia and continental Europe, feldspathic porcelains continue as the main porcelain types; while Britain still bases its best translucent china on the ashes of animal bones. However a 'fine china' material is now also made in Stoke-on-Trent, in parallel with bone china, in the form of true feldspathic porcelain with a lower-firing glaze. This is essentially a well-established American approach to the problem of making white translucent tableware, and it combines hard-porcelain with earthenware technology.

All these various recipes owe their origins to attempts to copy Chinese porcelain in the late +17th and early +18th centuries, and they embody the principle of 'remote transfer' through the process of superficial imitation. As for earlier examples of this process (calcareous earthenwares with tin-opacified glazes, and stone-paste bodies), tin-glazed earthenwares are still manufactured in Europe, the Near East, the Americas and North Africa, and stone-paste bodies remain common in the Islamic world. It is noticeable that 'porcelain's brother', celadon-ware, did not travel well. Moreover, after some interest in the late +17th and early +18th centuries, and some revivals in the +19th century, copies of I-hsing red stonewares fell from fashion in Europe. This leaves translucent white porcelain as the main ceramic influence from China.

It is apparent that some of the Italian, French, Spanish, German and English manufactories described in this section achieved the manufacture of porcelain in different ways to those pioneered in China. As was the case for other regions of the world, differences were in part explained by the nature of raw materials available. Another factor was the late development of high-temperature kilns, as existing

[225] Celoria (1976), pp. 27–8.

European ceramic industries were mainly based on production of majolica, faience and other earthenware types. Lastly, one should consider economic and social factors, that first caused Chinese porcelain to be imported into the West, then developed a market for that rare and decorative material and lastly, sought ways to replicate it. That manufacture did not cease after the +18th century, but economic and social conditions did, leading to a shift in the balance of power between East and West.

China's Decline in the Late +19th and +20th Centuries

The Industrial Revolution in Europe powered huge increases in manufacturing output, including the factory production of ceramics. In Britain, as we have seen, this led to novel solutions to the problem of concocting hard bodies and durable surfaces. Some recipes, such as those of Dwight and Cookworthy, were quite close matches to Chinese porcelain from Ching-te-chen. Others, such as bone ash and soapstone porcelain and Jasper ware, were unique formulations unlike anything made in East Asia or Europe.

In China, by contrast, innovation and production were declining. This was mirrored by China's political and economic wane.[226] Traditional policy of the Ming and early Chhing dynasties had been to preserve the stability of empire by restricting and controlling contact with other lands, a stratagem that limited trade (see pp. 714–18). This mandate was always harder to maintain in the coastal provinces of south China, and by the late +18th century China faced thrusting and aggressive expansion by European trading ventures, chiefly through the port of Canton. The various East India Companies were private trading associations, but they were backed by state power. In the case of the English East India Company, for example, trade with China produced revenue that not only enriched the home market, but also helped support the British Empire in India. The problem was that Britain produced very few goods that China wished to buy,[227] and the use of gold and silver bullion for purchase could not be sustained. Starting from the early +18th century, English East India Company ships started to convey Bengal opium on from ports in South-east Asia, and by the early +19th century opium addiction had become a problem in China. Opium replaced bullion as the major British trading commodity, and its carriage to China was ruthlessly exploited. Chinese official corruption and organised smuggling by secret societies (*hsiung-ti hui* 兄弟會) helped distribution

[226] Many authors have charted the political, social and economic decline of China in the +19th and early +20th centuries. For a good overview, see Fairbank & Reischauer (1973) and the bibliography of that book.

[227] Until the mid +18th century, no British ships could dispose of more than a proportion of their stock: English woollen goods, a staple home product, were particularly unsuccessful. In +1699 the East India Council for China wrote from Canton to the Court of Directors in London: 'We cannot tell what to advise your Honours to send to these parts, the Natives being fond of nothing but silver and lead; and probably if the rest of your Goods were thrown over board at Sea, your Cargoes home would not be much the less.' Morse (1926), p. 114.

of the drug. The first Anglo-Chinese War of +1839–42 was precipitated by the Chinese government's efforts to suppress the contraband trade. Humiliating defeat was followed by treaties that gave Westerners special privileges in China, and led to the establishment of European-controlled enclaves within China's sovereign territory.

China's relative military weakness was accompanied by a slowness to modernise political, economic and philosophical systems, that were outpaced by developments in the Western world, and (by the late +19th century) in Japan. Nowhere was this discrepancy more visible than in the context of science and technology.

Situation in the Chinese Ceramics Industry

China's overall economic recession, partnered by her lack of progress in modern science and technology, had consequences for the ceramics industry. Her export trade was affected, because many Western countries developed their own factories, and lack of innovation left China less able to supply fresh forms and novel products. Her home market was jeopardised by economic decline and periodic civil war. Thus by the late Chhing dynasty and during the Republican period, many kilns once famous for their high-quality wares were reduced to making low-quality domestic items for purely local markets.[228]

In the south at Ching-te-chen, production was hampered by these problems and also by internal labour issues. A slackening in court and government management of the imperial factory, and restrictive working practices, both played a part. Perhaps most significant of all was the fact that by the +19th century, the gap between exquisite handicraft skills and slowness to mechanise prevented competition with other domestic and imported products.[229] At the same time, owners of ceramic businesses had to be members of one of the guilds (mentioned on pp. 212–13), or form a partnership in which one of the members belonged. The sanction of the guilds were required before a newcomer could begin manufacture and the guild also approved beforehand what types of ware could be made and mandated only approved wares.[230] Fees were pre-determined, and conditions very restrictive. Traditional guilds continued to influence manufacture at Ching-te-chen until +1949, and their omnipotence had some unfortunate side-effects. One was the formation of secret societies, ostensibly to protect workers' interests but in fact leading to undesirable and even criminal activities. Another was over-elaborate demarcation of manufacture, rendering Ching-te-chen uncompetitive both at home and abroad. In +1928 the industry still produced open forms (*yüan-chhi* 圓器) and closed forms (*cho-chhi* 琢器) separately, and within those two categories of manufacture no fewer than 23

[228] This trend was marked in north China. In Shantung province, for example, kilns that made fine wares in the Sung and early Ming dynasties were, by the late Chhing and Republican periods, turning out low-fired earthenwares for peasant clients. These goods were studied in detail by one of the authors (RK) during a study trip to Chi-nan 濟南 in +1982.

[229] Dillon (1976), p. 11.

[230] Wright (1920), pp. 191–2.

types of ware were listed as being made at different workshops.[231] Further recession was caused by the Japanese occupation of China in the later +1930s, so that by the middle of the +20th century the ceramic industry at Ching-te-chen was in major decline, and recovery did not take place for a further two decades.

At the very period in the mid +19th century that the Ching-te-chen ceramic industry was in recession, however, Western interest in its product reached a new level. This interest was expressed in efforts to understand the nature and properties of porcelain through scientific study. Analysis of raw materials followed by practical synthesis, constituted a new method of transferring technology.

[231] Anon. (1959a), pp. 288–94, 298–9. A table on p. 298 shows the different types of wares, along with their guild affiliations.

RECONSTRUCTIVE TRANSFER THROUGH CHEMICAL ANALYSIS

Despite numerous European experiments, and some notable successes, little analytical work on Chinese porcelain materials was carried out until the mid +19th century, by which time the commercial urgency to understand the material had largely abated through the creation of so many usable Western porcelain recipes. However, in +1844 a Chinese priest, Father P. J. Ly, sent samples of kaolins, porcelain stones and glaze materials from Ching-te-chen to the Sèvres factory near Paris, where they were subjected to full quantitative analysis. The study and the interpretation of these raw materials were undertaken by Jacques Joseph Ebelman (*b.* +1814) and Louis Alphonse Salvetat (*b.* +1820), Administrator and Chief Chemist respectively of the Sèvres National Manufactory (see p. 38). Their results were published in +1851, and most of the mistaken ideas still current about Chinese porcelain can be traced to this +1851 paper.[232]

Ebelman and Salvetat believed that they had shown that Chinese porcelain stones and kaolins were very similar to the pegmatites and china clays then used at Sèvres, although the particle sizes of the Chinese rocks seemed much finer. In their view, Chinese porcelains (like European porcelains) were essentially feldspathic, although the firing temperatures of the Chinese bodies were rather lower than European hard-pastes, most of which were fired between 1,350°C and 1,450°C, from the Meissen ancestry of their recipes.

This view of Chinese porcelain, as being essentially a feldspathic material, remained unchallenged until +1900, when the most comprehensive study of Ching-te-chen materials and manufacture ever written was published by the then Technical Director of the Sèvres National Factory, Georges Vogt (see pp. 216–19). Vogt's study was based on raw materials, prepared bodies and glazes, and samples of porcelains made from known ingredients, collected by Scherzer. Scherzer also supplied detailed notes of body- and glaze-recipes, as well as drawings of Ching-te-chen kilns, to accompany and to explain his extensive range of samples.

Vogt's main discovery was that Chinese porcelain was essentially micaceous, with the mica operating both as a plastic material in making, and as a body-flux in firing. The extreme fineness of this mica had been overlooked by his predecessors at Sèvres, and hence their assumption that the Chinese material was feldspathic. Most of the feldspar that Vogt found in the Ching-te-chen materials proved to be of the sodium type, where it operated as a secondary flux in the porcelain bodies and glazes. Vogt did confirm the firing temperature of late +19th-century Ching-te-chen porcelain to be about 1,290°C, and he was able to use his analyses to design a new

[232] Ebelman & Salvetat (1851).

feldspathic porcelain, 'Modern Sèvres' (coded PN, *pâté nouveau*) as a supplement to the old high-firing Sèvres hard-paste body.[233]

Vogt's PN porcelain was designed to re-create a typical late +19th-century Ching-te-chen porcelain body oxide for oxide, although it used potash feldspar as its main body-flux, in the European manner. However, Vogt also developed at Sèvres a series of body- and glaze-recipes based on potassium mica.[234] Unlike the PN recipe these did not go into production, but they seem to mark the first conscious use of potassium mica in European porcelain research. Even so, it does seem that Vogt may not have quite appreciated that Chinese porcelain stones and kaolins contained mostly secondary mica ('hydromica') rather than primary potassium mica, with its coarser structure and lower natural water content. Despite this omission, Vogt was a very thorough analyst and scientist, and he had noticed that the quantity of water in the mica fractions derived from the Chinese porcelain stones was 'in general a little higher than it ought to be . . .' but he rather 'shrank from the difficulties of directly determining . . .' their true water contents, because of the temperatures at which the chemically bonded water were lost.[235]

As well as this important work on reconstructing Ching-te-chen porcelain bodies, Georges Vogt also successfully imitated numerous low-temperature and high-temperature +19th-century Ching-te-chen glazes, particularly the Chinese high-temperature copper-red that had become something of a Holy Grail to European glaze researches in the late +19th century. Chinese copper-red monochrome glazes were also reproduced successfully by Hermann Seger at Berlin, sometime in the +1880s. Seger also designed his own version of East Asian porcelain, but this time based on analyses of +19th-century Japanese wares, which were more siliceous than those of China. Like Vogt's PN body, Seger's so-called 'soft porcelain' used feldspar as a body-flux. The material was inferior to contemporary German hard-paste (as Seger noted) although substantially lower-firing.[236]

PETRIK'S PORCELAIN

Vogt and Seger, working at Sèvres and Berlin respectively, were major contributors to European porcelain research, but their 'reconstructed' versions of East Asian porcelains were anticipated to some extent by the work of the Hungarian L. Petrik in the +1880s. Petrik designed a true micaceous porcelain using Hungarian raw materials that was intended to be 'similar to the oriental ware'.[237] The body consisted of: illite (secondary potassium mica) 46%, rhyolite rock (feldspar 50%, quartz 50%) 15%, and quartz 39%. The firing temperature was Cone 8 (1,250°C). Petrik's

[233] Vogt (1900), p. 604. The recipe is: kaolin 42, potash feldspar 38.7, quartz sand 26.
[234] *Ibid.*, pp. 603–12.
[235] *Ibid.*, p. 550.
[236] Seger (1902d), p. 725. The essential recipe for 'Seger porcelain' was quartz 45, feldspar 30, and clay substance 25. This was achieved with various raw materials. Seger gives the maturing temperature as 1,300°C.
[237] Petrik (1889), pp. 1–10.

original pieces have been lost, but were described as being: 'especially beautiful . . . They withstood firing without softening and were very white and translucent.'[238] Their quality owed much to the Koromhegy illite used, as this produced a body with an iron oxide content of only 0.1% Fe_2O_3, even purer that the finest Te-hua 德化 porcelain.[239]

Late British Hard-Paste Porcelains

Attempts to re-create Chinese porcelain for the industrial market continued into the +20th century, with a particularly good approximation to the Chinese material being made at Stoke-on-Trent as part of a government-funded project to make true hard porcelain from British raw materials. The work began in the spring of +1917 and was undertaken by the potter Bernard Moore and the ceramic scientist J.W. Mellor. An account of this work was published in +1930.[240] The key material for the new porcelain was Dry White Cornish stone, the rock probably used by Cookworthy for much Plymouth and Bristol hard-paste. Moore and Mellor designed a series of very successful recipes based on Dry White stone that matured at about 1,250°C, a temperature familiar to Stoke-on-Trent potters as the usual firing temperature for bone china biscuit-ware.[241] This porcelain was not adopted by the Staffordshire pottery industry for the unusual reason that it needed to be fired in reduction, and the high-iron fireclays used for saggars in Stoke at the time tended to fail in reducing atmospheres. At present, the only British hard-paste based on Cornish materials is that made by Highland Stoneware at Lochinver in Scotland, using a recipe consisting largely of Hard White stone, and developed by one of the authors (NW) in +1990.

Artist Potters

The main Chinese influences on the West's ceramics industries in the +18th and +19th centuries were translucent white porcelains, usually decorated with underglaze-blue painting or with overglaze enamel decoration. I-hsing red stonewares and monochrome-glazed porcelains such as Chinese copper-reds were also imitated, and inspired their own minor traditions. As excavation in China in the early +20th century accelerated, however, assisted by road and railway construction

[238] Mattyasovszky-Zsolnay (1946), p. 258.

[239] *Ibid.*; the lowest Fe_2O_3 figure for traditional Te-hua porcelain bodies given by Guo Yanyi & Li Guozhen (1986), p. 143, table 1, is 0.2% for some Ming wares.

[240] Moore & Mellor (1930).

[241] One particularly successful recipe was: Dry Cornish stone 55, ground white sand 12, ball clay 5 and China clay 28. The authors, Moore & Mellor (1930), p. 260, note: 'It resembles the Chinese rather than the Japanese or the French type . . . it is particularly strong, and very suitable for making jugs, teapots, jardinières and large vases . . . Using feldspar as the flux the product is not so good; the body then tends to assume a glassy structure, resembling the old Japanese, or the so-called Seger porcelain. This type is very brittle and breaks readily when struck.'

in the north, the full extent of China's ceramic past began to be revealed to Europe. That heritage included a wealth of medieval stonewares and early porcelains. These proved of especial appeal to Western artist-potters, of whom Bernard Howell Leach (+1887–1979) was perhaps the most influential. Leach combined a deep empathy with East Asian aesthetics with unusual insight into the technology of Chinese, Korean and Japanese ceramics.

Leach's detailed knowledge of East Asian raw materials and working methods came from his practical experiences as a traveller and potter in China and Japan in the first two decades of the +20th century. From this background he was able to make informed guesses on how numerous Sung and earlier glazes had been constructed, and how the wares had been made, decorated and fired. These ideas were incorporated in his +1940 manual *A Potter's Book*, now in its ninth edition. This important work contained, amongst other insights:

- The first full Western description for the use of wood ash in East Asian glazes
- An accurate account of how early south Chinese stoneware glazes were made from mixtures of siliceous clays and common ash, together a typical recipe (60 siliceous clay, 40 wood ash) since confirmed by analysis of Chinese wares
- The non-feldspathic nature of early Chinese blackware glazes
- Recipes for making *chhing-pai* 青白 glazes that gave fired results chemically identical to the Sung originals
- Recipes for Korean celadons that also closely matched true Koryŏ glazes
- A black slip for Tzhu-chou-style 磁州 painting based on magnetic iron oxide, a material recently established as essential for the Tzhu-chou black underglaze effect
- Good accounts of the natures of Japanese and Chinese transparent and opaque overglaze enamels
- A celadon body-recipe based on adding red clay to white porcelain, now shown to have been the standard Lung-chhüan 龍泉 method

This last material was used as the basis for fine thrown tableware at Leach's pottery in St Ives in Cornwall in the +1940s and was one of the first Western demonstrations of the potentials of the celadon material as a fabric for fine tablewares.

Bernard Leach also supplied plans in *A Potter's Book* for oriental wood-fired kilns and throwing wheels and many practical descriptions for turning, the use of fired-clay moulds, clay-planes and spout-moulds, all derived first hand from Chinese and Japanese workshops. The book also contains a lively defence of the East Asian aesthetic with regard to ceramics. That section became as influential to potters in its time as the techniques and recipes supplied in the text.

Leach was far from being a chemist and he worked from observation, experience, intuition and insight, rather than from direct chemical analysis. His work can be regarded as a rather special case of 'local transfer', albeit transferred from China and Japan to the igneous landscape of Cornwall, England, in the +1920s, where Leach established a pottery in St Ives on his return from Japan. The St Ives pottery



Fig. 172 Teapot and covered jam-pot, with incised decoration and celadon glaze, made at the Leach pottery in St Ives, +1949

used a multi-chamber wood-fired climbing kiln designed and partly built by the Japanese kiln-expert Matsubayashi Tsurunosuke.

The heyday of Leach's influence was seen in the +1960s and +1970s when thrown reduction-fired stonewares became immensely popular among artist potters in the West, particularly in England and North America. This can be regarded as the last full-blown influence of Chinese ceramics on the course of Western ceramic traditions, although in many cases the influence came as much from Leach's reworkings of East Asian ceramic styles and techniques, as from the original objects he admired.

Knowledge from Chemical Analysis

In the last quarter of the +20th century, writers on the subject of Chinese ceramic technology have been able to draw on the hundreds of chemical analyses of Chinese wares that have been made in China and the West, as surer guides to reconstruction. Publications by Tichane, Kingery, Vandiver, Wood, Li Chia-Chih, Chang Fu-Khang and a number of other authors in East and West, are detailed in Bibliography B and Bibliography C. Understanding of traditional ceramics through scientific analysis was an approach pioneered by the Shanghai Institute of Ceramics, alongside their major research effort to develop new materials. Both of these areas of investigation typify work on ceramic materials in the later +20th and +21st centuries.

THE SIGNIFICANCE OF CHINESE CERAMICS IN THE CONTEXT OF WORLD CERAMIC TECHNOLOGY IN THE +20TH TO +21ST CENTURIES

TECHNOLOGICAL DEVELOPMENTS

Throughout this volume the remarkably early development of, and achievements in, Chinese ceramic technology have been emphasised. The extent to which other countries consumed her outstanding products has been outlined, as have attempts to emulate those products by means of direct, remote and reconstructive transfer. By the late Chhing period, however, China seemed to have exhausted her capacity to innovate. She was still exporting low-quality wares to destinations in South-east Asia, the Middle East and Africa, but had lost key quality markets in Japan, Europe and North America. Those countries were, by contrast, developing major technical industries that included the mass-production of ceramics. This was noticeable in 'traditional' ceramic production (table and sanitary wares), but became much more significant in the context of new, high-technology products.[242]

After the Revolution of +1949, the new Communist government made development of science and technology one of its priorities. The major loci of scientific research were merged to create one body, the Chinese Academy of Sciences 中國科學院 (CAS). During the +1950s a series of internal reorganisations were instituted, to bring CAS in line with the Soviet Union's All-Union Academy of Sciences, on which it was based.[243] Although the Chinese government launched initiatives to persuade foreign-trained Chinese scientists to return to the mainland,[244] the major sponsor of Chinese science during the +1950s was the Soviet Union.[245] This was reflected in the Chinese State's First Five Year Plan, organised with Russian assistance, that established twelve research priorities, several of them involving staff

[242] China did produce her first scientific journal as early as +1876, but its distribution was very limited, see Wu & Sheeks (1970), p. 388.

[243] Pre-+1949 Chinese science was represented by a body called the Science Society of China, founded in +1914 by Chinese students studying in the US, whose numbers never reached more than 1,500 before +1949. *Ibid.* By +1950 Academia Sinica 中央研究院 was centred in Nanking. This was merged with the National Academy of Sciences 國立科學院 in Peking to form a body comprising twenty specialist institutes. By the mid +1960s this had grown into an enormous research organisation with some 120 institutes. Suttmeier (1980), p. 31.

[244] In May +1950 about 20% of natural scientists originally from China were still abroad. The majority trained in the United States, and most of the rest in Japan and Europe. By the end of +1952 over 1,500 students had returned to China, but by +1958 it was estimated that about 10,000 remained in the USA, England, France and Japan. See Lindbeck (1960), pp. 6–9.

[245] By the end of +1958 6,572 students had been sent to the Soviet Union to receive training at both undergraduate and postgraduate level. Additionally, several hundred scientists, advanced students and technicians had their qualifications upgraded by periods of research in the Soviet Union. Soviet scientists were sent to China to initiate and organise research programmes: 'over a hundred Soviet experts were at work in Peking alone by November 1957'. *Ibid.*, pp. 19–22.

working in institutes concerned with ceramic materials.[246] The research priorities of the early +1950s reflected the current view that the first duty of science was its service to industry, agriculture and national security. With the disastrous failure of the Great Leap Forward (大躍進 +1958–60) and the Sino-Soviet rift of late +1960, emphasis shifted to predominantly economic objectives, and was geared to immediate practical needs.[247] Many research projects were abandoned as priorities in the early +1960s, and work switched to areas that reflected China's capacities and concerns, namely life sciences and defence.[248] That period of 'economic retrenchment and recovery' +1960–65 was severely disrupted by the decade of the 'Great Proletarian Cultural Revolution' (文化大革命 +1966–76), causing major setbacks to science, technology and industry.[249] Research institutes were closed, their expert staff dispersed to undertake menial labour in outlying regions. Those with Western connections, including those who had trained overseas or who had contact with colleagues in foreign countries, were persecuted and (in some cases) driven to death. After +1977 work and international contacts were gradually resumed.

New Developments in the Manufacture and Use of Ceramics in the +20th to +21st Centuries

In order to clarify what Chinese scientists investigating ceramic materials were working on after +1949 and especially in recent decades, it is necessary to outline what the term had come to mean in the international scientific community by the second half of the +20th century.

In parallel with the refinement of traditional ceramic processes, that era has brought forth some unprecedented developments. These have been characterised as being part of the 'new materials revolution' that saw the formulation of unique substances in metals, ceramics, polymers and composites. Advances in research and manufacture took place in many countries, so that it would be correct to describe fine ceramics science and technology as being a truly global phenomenon. Some nations, such as Japan, Korea and North America, progressed more quickly than others. However, it may well be that in the +21st century expanding economies on the Pacific Rim, among them China, will move to the fore as by the +1990s Chinese

[246] The priorities were: atomic energy, radio electronics, jet propulsion, automation and remote control, petroleum and scarce mineral exploitation, metallurgy, fuel technology, power equipment and heavy machinery, harnessing of the Yellow and Yangtze rivers, chemical fertilisers and the mechanisation of agriculture, public health and basic sciences. Suttmeier (1980), p. 32.

[247] Wu & Sheeks (1970), pp. 44, 390–6.

[248] Suttmeier (1980), p. 33.

[249] The impact of that tumultuous period was little understood in the West at the time. In +1970 an American fact-finding study solemnly reported that: 'The Great Proletarian Cultural Revolution, so far as is known, had no significantly detrimental effect on Chinese R&D, in spite of its disruption of the orderly process of education.' Wu & Sheeks (1970), pp. 390–1.

and Taiwanese universities, research institutes and industrial companies were all involved in the race to invent and exploit advanced ceramic materials.[250]

When speaking of modern materials the term 'ceramic' has broad parameters. As we have seen, the most common and useful silicate minerals are pottery clay, kaolin, high-alumina clay, refractory clay, porcelain stone, feldspar, quartz and silica sand.[251] Prior to the second half of the +20th century, a broad definition of ceramics would encompass pottery, porcelain, glass, clay-based building products, refractories used in metal-casting, kiln-construction and saggers, enamel,[252] portland cement[253] and abrasives.[254]

The last 60 years have witnessed further important breakthroughs in the history of ceramics. The first example was the preparation of aluminum oxide (Al_2O_3) ceramics. During the Second World War German scientists experimented with laboratory-prepared aluminum oxide powders sintered at very high temperatures, to produce ceramics with superior mechanical, chemical and electrical properties.[255] These new, chemically purified ceramics were used to insulate high performance spark plugs in aeroplane engines, and their successful preparation paved the way for a variety of 'advanced ceramics'. In the +1950s scientists found that not only Al_2O_3, but also many other artificially prepared inorganic non-metallic compounds such as

[250] For example, among delegates to the Forum on New Materials at the World Ceramics Congress at Florence in June/July +1994, were representatives from many institutions, listed by themselves as coming from: the Canton Research Institute; the Ministry of Electronic Industry, Hunan University; Tsinghua University, Peking; Wu-han University of Technology; Sian Chiao-thung University; Kirin University; Thai-yüan University of Technology; Shantung Institute of Building Materials; Harbin Institute of Technology; University of Science and Technology, Ho-fei, Anhui; Chung-shan University, Canton; Peking Centre of Physical and Chemical Analysis; Peking Research Institute of Materials and Technology; Nanking University (working in partnership with Hong Kong Baptist College, Kowloon); Hua-Chung University, Wu-Han; Shanghai Institute of Optics and Fine Mechanics, Academia Sinica; Chinese Academy of Medical Science, Thien-chin; Urumchi Western Region Hospital, Sinkiang; National Cheng Kung University, Tainan; National Chiao Tung University, Hsinchu; Feng Chia University, Taichung; National Taiwan University, Taipei and National Sun Yat-sen University, Kaohsiung. From research projects reported at such fora it seems that most Chinese researchers are working on the detailed minutiae of materials' development and manufacture. Outside China, first-, second- and third-generation Chinese scientists and technicians are involved in frontline research teams in many countries of the world.

[251] See Anon. (1994b); Encyclopaedia Britannica CD TM.

[252] A development of the technique employed as a decorative medium on ceramics, its technology being essentially the same as 'Canton' enamel on metal. Enamelling of cast-iron and sheet-steel was developed in Germany late in the +19th century, and this technology was soon introduced into many other countries. Modern metal enamelling techniques often use fluoride opacification, a process that was pioneered in Thang dynasty glass and transferred to cloisonné-enamel glasses in the early Ming dynasty.

[253] The origin of hydraulic cement goes back to classical Greece and Rome. Portland cement was first developed by a British engineer John Smeaton in +1756. The industry was developed in the United States from *c.* +1875, and has spread very rapidly to countries all over the world to meet the huge demand of this material for road and building construction.

[254] The use of abrasives goes back to earliest man's rubbing of one hard stone against another to shape a weapon or tool. Ancient Egyptian drawings show abrasives being used to polish jewellery and glass vases. In Neolithic China, jade objects were polished using natural abrasives. At the very end of the +19th century, a process was developed to make aluminum oxide and silica carbide abrasives in electric furnaces. In +1955, diamond abrasive was pioneered.

[255] This groundbreaking product was developed by scientists seeking to replace materials unavailable because of the allied blockade, cf. Kingery & Vandiver (1986a), p. 4.

carbides, nitrides, borides and halides, could be sintered and transformed into ceramics with special properties not found in silicate ceramics and other existing materials.[256]

The new ceramics, though having something in common with traditional ceramics, are different to them in many respects. In order to distinguish the former from the latter, new names were adopted for them in different countries. They have been termed 'industrial ceramics', 'functional ceramics', 'special ceramics', 'fine ceramics', high-performance ceramics', 'new inorganic non-metallic materials', 'advanced ceramics', among other names. Today, it seems that the last two names have been accepted by most people. At the same time, traditional definitions of ceramics must be modified to take account of the many new ceramics developed over the last 60 years. The definition used by the American Ceramic Society includes all materials of a non-metallic inorganic kind that are subjected to high temperatures during production and application; it thus includes synthetic crystals, amorphous materials, ceramic coatings and ceramic composites in addition to the eight major categories of ceramic listed above.[257] It seems certain that more categories of advanced ceramics will be added to the list in the future.

ADVANCED CERAMIC COMPOSITIONS

These new, man-made ceramics can be fabricated from a wide variety of raw materials other than clay, some not found in nature but artificially prepared in a laboratory.[258] The basic raw materials for traditional ceramics, i.e. silicates contained in sands, clays and rocks, are widely available and therefore relatively cheap.[259] These are the substances discussed in Part 2 of this volume. Advanced ceramics, however, are not made directly from sands, clays and rocks but from extremely pure, microscopic powders that require extensive chemical processing and are thus not cheap at all. These powders are consolidated at high temperatures to produce dense, durable structures with excellent mechanical, chemical, electrical, electronic and magnetic properties to meet the diversified needs of the 'new materials revolution', and the specific and critical requirements of high-tech products invented in the second half of the +20th century.

New varieties of advanced ceramics are constantly being experimented with, but some of the better known, and those that have already passed from the laboratory

[256] For discussion and listing of ceramic materials, see McNamara & Dulberg (1958); Cahn *et al.* (1994); Shih Chhang-Hsü (1994).

[257] Brook (1991), p. 488.

[258] A principle followed in China as early as the Warring States period for the manufacture of artificial pigments such as Chinese Blue and Chinese Purple, see pp. 610–12.

[259] This is because the most abundant materials in the earth's crust are oxygen (47%) and silicon (27%), and thus the most naturally occurring geological minerals are silicates, see pp. 42–4 and 76 of this volume and Kingery & Vandiver (1986a), p. 26; Weidmann *et al.* (1994), p. 175; Brook (1991), p. 419.

into manufacture, comprise silicate, oxide, non-oxide and mixed-composition ceramics. Silicate ceramics include steatite (largely consisting of talc) which is used for small parts of complex shape like electrical insulators. The silicate mineral pyrophyllite is used for tiles and refractories, and wollastonite for dialectric bodies and wall tiles.[260] Simple binary oxide ceramics include materials such as alumina, magnesia and zirconia. Alumina ceramics have great strength, hardness, resistance to abrasive wear and chemical attack, and operate well at high temperatures. Magnesia ceramics, composed from one of the alkaline-earth oxides, have a high melting-point and chemical stability and are thus an important refractory.[261] Zirconia ceramics have great strength, hardness and toughness, exceptional wear resistance and a low thermal expansion rate. They are chemically stable and will withstand great stress levels as well as high temperatures.[262] Ternary oxides such as barium titanate, strontium titanate, calcium zirconate, etc. are used for electronic ceramics. More complex oxide systems are synthesised to satisfy specific requirements.

Non-oxide ceramics include those made of nitrides, carbides, borides, silicides and halides.[263] Examples of such materials are silicon carbide (carborundum) and silicon nitrides, materials that not only display great hardness, strength, wear and corrosion resistance, but also outstanding resistance to thermal shock and an ability to maintain strength at high temperatures. Silicon carbide can resist high temperatures and corrosion, and is used in heat exchangers, burner parts and rocket igniters. Silicon nitride is tougher and has been used for car turbo charger rotors and other high-temperature applications, as well as ball bearings.

The possibility of mixing oxide and non-oxide ceramics has given rise to an extremely wide range of mixed-composition ceramic systems. One well-known type is sialon ceramics, a set of materials first synthesised in the +1970s, that are based on combinations of silicon nitride with aluminum oxide and other oxides. They have potential for high-temperature engineering components.[264]

FORMING PROCESSES

The forming and sintering methods used for advanced ceramics are usually quite different from those for traditional ceramics (described in Parts 1 and 4 of this

[260] Norton (1974), pp. 48–9. This is perhaps the most ancient glazed ceramic material in the world, first used in the -5^{th} millennium.

[261] Brook (1991), p. 283.

[262] A recent demonstration of appropriate materials' application was a research project undertaken by the University of Hull in partnership with a local manufacturing company. This consortium has built a high-pressure hydraulic pump made of zirconia which can be used in dirty sea water, see Shelley (1994). Most high-pressure pumps used in offshore drilling need to run in clean water, as sea water is the second most naturally occurring corrosive substance known after human bodily secretions. This requirement has made offshore drilling a very expensive process to date. Zirconia is also used for cutting tools in the plastics and paper industries.

[263] Brook (1991), p. 1.

[264] *Ibid.*, p. 415.

book).[265] There are three main reasons for these differences. Firstly, raw materials are different. Traditional clay-based ceramics have good plasticity when mixed with water and can be formed by free-hand forming, turning and throwing on the wheel, moulding, slip-casting, etc. (see Part 4).[266] By contrast, the raw materials for advanced ceramics are usually non-plastic in nature, so traditional forming methods cannot be used and many new techniques have been developed.[267] The second variance is explained by sintering temperatures being different. The sintering temperatures for advanced ceramics are usually much higher than those for traditional ceramics. In order to produce properly sintered advanced ceramics, various types of ultra-high-temperature furnaces with sensitive control devices, and many other high-tech sintering facilities and processes have been developed in place of ordinary kilns. The third reason is that the properties of the finished products are different. Advanced ceramics play an important role in the new materials revolution because of their specific mechanical, chemical, electrical, electronic, magnetic and other physical properties. In order to develop a certain desired property or a combination of desired properties, advanced ceramics are usually made by precisely controlling their chemical constituents and microstructure. These requirements dictated a variety of forming and sintering methods, each method having its own advantages and disadvantages. The selection of an appropriate method depends on the desired properties of the finished product, on the cost of manufacture, and other factors.

Forming and sintering are usually done separately, though recently some technologies have combined forming and sintering into one process. Common forming processes comprise die pressing, rubber mould pressing, extrusion moulding, slip-casting and injection moulding. In traditional moulding processes (when either dies or rubber sheaths are employed) solid, brittle ceramic powder particles are mixed with organic binders to enhance the fluidity of the powder and to lessen the danger of cracks and fracture as the compound is compressed to 200 to 2,000 kilograms per square centimetre. These inexpensive methods are used for refractories, tiles, electronic ceramics and nuclear fuel pellets.[268] Extrusion moulding is suitable for sewer pipes, hollow tiles and the ceramic honeycomb manufactured for car exhaust

[265] Sintering, the initial stage of the firing process in traditional kilns, is described in Part 1 on pp. 57–8. When ceramic materials are sintered they become a cohesive mass, without melting. Sintering is a solid state reaction as well as a liquid phase process, and the mathematics have been well formulated by Kingery and Coble. A good account of 'dry' sintering may be found in Singer & Singer (1963), pp. 171–3. The process of 'wet' sintering (sintering with a reactive liquid) is explained in Kingery (1960), pp. 386–9, where he notes on p. 386: 'We are referring to systems where the solid phase shows a certain limited solubility in the liquid at the sintering temperature; the essential part of the sintering process is the solution and reprecipitation of solids to give increased grain size and density.' Unlike traditional pottery, sintering processes for advanced ceramic materials can reach extremely high temperatures to produce substances with great strength.

[266] In addition to clay-based wares China also pioneered the use of non-clay ceramics early on, when in the Warring States period glass-bodied beads were manufactured (see pp. 474–8). At later periods non-clay vessels were made, such as Lung-chhüan wares, whose body-composition often approximated to 50% quartz–50% mica (see pp. 254–8), and Wood (2002), pp. 21–3.

[267] New forming solutions that bear some conceptual points of comparison, were those arrived at empirically by potters in the Shang dynasty, when they designed sophisticated and precise mould-making techniques and materials (see pp. 102–4, 396–405).

[268] See Kuo Ching-Khun (1997).

purification. In the traditional technique of slip-casting powders are mixed with water and deflocculants, while in injection moulding powders are mixed with wax which allows the production of complex shapes but means that the production cycle is longer owing to the difficulty of removing the wax (which comprises 15–25% of the moulded product).

New forming methods include colloidal processing, performed by consolidation of a dispersion of nanometre to submicrometre-sized powders in a liquid media. Centrifugal slip-casting combines the advantages of colloidal powder preparation with efficient densification methods. Functional ceramic fibres and films can even be prepared by powderless methods, by the sol-gel process.[269] Vapour deposition is used for fibres and coatings.

When advanced ceramic shapes have been formed they are sintered using various techniques. Standard pressure sintering (or hot-pressed sintering) is most common and produces porcelain and refractories as well as new ceramics such as alumina. In hot pressing, powders are placed in a mould and sintered under high pressure to produce such ceramics as silicon nitride, silicon carbide and aluminum oxide; the process is expensive so its use is limited. A technology with great potential for the future is hot isostatic pressing (HIP) that produces ultra-high-strength materials hot pressing using gas pressure to obtain isostatic pressure. Ultra-high-pressure sintering can synthesise such materials as diamonds, while reaction sintering utilises chemical reaction to affect the process. Since the mid +1970s work has gone on to produce advanced non-oxide ceramics like silicon carbide and silicon nitride by chemical formation at lower temperatures (in the 800–1,200°C range). Microwave sintering of ceramics was first reported in +1978, and although it can give rise to improved densification of ceramic materials like alumina, zirconia and silicon nitride, as a process it is not well understood at present. Other new techniques include the dynamic compaction of ceramic powders with or without heat by explosive, spark plasma sintering, self-propagating high-temperature synthesis and the simple method of flame spraying, when fine ceramic particles are melted in an oxy-acetylene flame and sprayed on as a shell to cover a substrate.

THE USE OF MICROSCOPY

Late +20th-century advances in theoretical understanding of the structure of physical and biological matter, coupled with improvements in experimental technique and in processing technology, have meant that for the first time manufacturers can identify needs and then attempt to develop a material specifically tailored to meet those needs.[270] A vital contribution to experimental technique in new ceramics materials is microscopy. Years of laboratory research revealed that the unique

[269] Sol-gel chemistry has been used since the +19th century to make inorganic compounds in powder form; since the early +1970s, the method has increased in commercial importance. Brook (1991), p. 176.

[270] Clark & Flemings (1986), p. 43. Attempts to synthesise materials have only sometimes been successful.

properties of advanced ceramics have a close relationship to the composition, manufacturing process and microstructure of finished products. Therefore, advanced analytical and testing apparatus and related techniques were developed to control and improved the desired properties of products. Among these, microscopy is especially important. In recent years scientists have extended the use of the electron-microscope and now also employ scanning tunnelling microscopes. The latter machines can look at materials at very great degrees of enlargement (up to several tens of thousands of times) and thus can inspect structures at an atomic level. Some experimental materials have literally been built atom by atom. STM allows observation of individual atoms on the surface of materials, and also allows those atoms to be manipulated. So ceramics scientists are no longer working blind and hypothesising; one of the keys to modern development has been microscopy. Resulting innovations in microstructural and chemical design have allowed ceramists to synthesise whole new classes of materials with unique properties. A potent example is provided by the development of silica-based optic fibres for telecommunications systems.[271]

APPLICATIONS

In general, the advanced ceramics produced by the methods outlined above are not end-products. Rather, they are assembled into components critical to the successful performance and operation of large, complex systems such as computers, aircraft, space vehicles, electronic devices and cars. The most successful uses made of advanced ceramics have been in mechanical applications, and as small components in electrical, electronic and photonic functions.

The earliest use of advanced ceramics, as we have seen, was as an electrical insulator. Since the +1940s booming industries have given rise to a great diversification of electrical and electronic ceramics, based on two types of material. Magnetic materials are based on the principles of ferrimagnetism, while dielectric phenomena such as ferroelectricity and piezo electricity support other developments.[272] Electrical and electronic uses ensure that advanced ceramics are integral to the development of computers, videos and circuitry in high-speed machines.

Mechanical applications can be divided between those used at ambient temperature, and those employed at elevated temperatures.[273] Applications at ambient temperature include wear parts for medical engineering (orthopaedic and dental implants), process plant (pump components, valve faces, lining for pipework) and mechanical engineering (bearings and valves). A key drawback to these kinds of use is the inherent brittleness of ceramics (see below) which can result in sudden and complete failure of a component. Mechanical applications at high temperatures are

[271] Bowen (1986), p. 149.
[272] Brook (1991), p. 1.
[273] *Ibid.*

a key target for development, for example in high-speed machining and in heat engines. Ceramic nuclear fuels and radioactive nuclear-waste immobilisers are another growth area.

Three categories of product that use advanced ceramic materials are singled out for special mention here, namely refractories, semiconductors and superconductors.

REFRACTORIES

Traditional refractories for mould-making, kiln lining and kiln furniture used suitable, locally available fireclays (see Part 3 of this book). In the +20th century, the composition of insulators was refined to include purified materials prepared using processing methods detailed above, for high- or ultra-high-temperature use in spark-plug cores, thermal nuclear reactors, electrodes for industrial furnaces, aerospace engines, etc. The materials include pure oxide refractories (alumina, beryllia, magnesia, silica, zirconia, zircon, mullite, tin oxide); nonoxide refractory bodies (the borides, especially those using titanium and zirconia); the carbides, especially silicon, tungsten, titanium and boron carbides; man-made carbon and graphite; and the nitrides, especially those using silicon and boron.[274]

SEMICONDUCTORS

Semiconducting materials do not conduct electricity at low temperatures or in a pure state, but do so at high temperatures or when very slightly impure. A main thrust of solid-state physics research is to advance semiconductor technology for the electronics industry. Semiconducting ceramics are used in the construction of integrated circuits, injection lasers and microwave devices. In China, research on such materials is carried out in several places, foremost among them the Institute of Semiconductors 中國科學院半導體研究所 (part of the Chinese Academy of Sciences in Peking), while work on injection lasers is also carried out at the Institute of Physics 中國科學院物理研究所, the Institute of Optics and Precision Instruments 中國科學院物光學和精密器研究所 and Peking University 北京大學. Most universities not only engage in work on integrated circuits but also have production lines on campus, for the foremost aims are to train technicians with manual skills and to raise revenue. Thus, for example, complete production lines for circuits were established at Tsinghua University 清華大學 in Peking and Fu-tan University 復旦大學 in Shanghai.[275]

SUPERCONDUCTORS

The conduction of electricity without the slightest loss of power and with perfect efficiency has been a goal of science since the beginning of the +20th century. Unlike

[274] Norton (1970), pp. 433–6; Norton (1974), pp. 254–7. For development of Chinese refractories see Zhong Xiangchong (1998), pp. 50–5.

[275] Bloembergen (1980), p. 98.

the current use of sheathed copper wire to conduct electricity supply, the employment of superconducting ceramic oxide wire could achieve this goal, and could lead to developments such as: nuclear and solar generating factories sited far from human habitation; powerful and efficient lightweight magnets and motors; magnetically levitated bullet trains able to travel at hundreds of miles per hour; or long-term energy storage systems.[276] Superconduction only takes place at extremely low temperatures, and in the +1960s to +1980s successful commercial applications such as the building of hugely powerful electromagnets made of niobium and tin or niobium and titanium, needed then to be cooled to within a few degrees of 0° Kelvin (absolute zero, or −273°C). They were utilised for medical imaging instruments called nuclear-magnetic resonance machines (NMR) which produce X-ray-like photographs of the inside of the body, in particle accelerators, and in junction devices in sensitive field detection systems. In +1986, two Swiss scientists produced a paper that led to a race to invent superconducting compounds that were viable at higher temperatures. Leaders in the race included a team from the University of Houston, Texas, led by a Chinese-American Paul Chu and containing several Chinese and Taiwanese members, and a team at the Institute of Physics in Peking.[277] Since the late +1980s, however, practical applications for high-temperature superconductors have been surprisingly few, as material issues remain a serious obstacle to scientific and technological development. Progress is limited to the advance of theoretical models, and the building and testing of prototypes. High-temperature superconductors were, by the late +1990s, materials of promise rather than commerce.

DOMESTIC PRODUCTS

In addition to uses in industry, some advances have been made in the domestic product field. These include components used for telephone lines, telephones, televisions, videos, video camera recorders, control devices, over-heat and over-load protection devices, watches and cameras. Also affected is the manufacture of jewellery, of ceramic faced golf putters, of ceramic balls for ballpoint pens and of knives and scissors with toughened blades. The uses of advanced materials, including ceramics, is at present concentrated where money for research and development is provided, i.e. aerospace, electronics and engineering. Often lengthy delays ensue between invention of new materials and their commercialisation, for the cost of bringing new materials into mass-production is prohibitive.[278]

[276] Hazen (1988), p. xix.

[277] *Ibid.*, pp. xxiv, 32, 40, 81, 192.

[278] A classic case of the delay in developing laboratory-based ideas into practical products concerns the micro chip. As early as the +1950s, American scientists Robert Noyce and Jack Kilby etched whole circuits on to one sliver of silicon rather than wiring up lots of silicon transmitters, to minimise costs. However, it was only when the Apollo space programme and the Pentagon ordered silicon chips in enormous numbers, that commercial pressure forced manufacturers to find a way of mass-producing them. Mass-production ensured a steep fall in prices, which in turn led to cheap computer circuits, and ultimately enabled householders of the +1980s to buy their own home computers. Cf. Hazen (1988), p. xix.

COST FACTORS

The generally low cost of raw materials has already been mentioned. Nevertheless, the cost of producing ceramic components is still extremely high owing to the expense of manufacturing pure powdered raw materials and the fact that many production units are still at the pilot stage and therefore small scale. Shrinkage occurs in firing and components that have to meet fine tolerances have to be ground at the end of fabrication, by techniques such as diamond drilling because the substances are so hard. Reject rates are often high. Expense and high shrinkage represent the 'bottleneck' in ceramic processing and therefore in the commercialisation of advanced ceramics, especially for structural applications where machining defects control the reliability of components. Reject rates are bound to be high, because of the high stresses and strains that ceramic elements in engineered products must withstand. The degree of accuracy required in all new materials' applications means that stringent testing procedures must be applied. Advanced materials must be controlled at microscopic levels all through the production process, unlike traditional materials that could be checked for quality and homogeneity by taking samples. For example, during the Ming period at the imperial kilns at Ching-te-chen, batch samples were taken during manufacture and firing. In spite of this, wastage rates were high and many products that left the kiln were subsequently destroyed because of imperfections.[279]

REASONS FOR THE USE OF ADVANCED CERAMICS

The chief reason for the use of new materials is that advanced ceramics have useful qualities that cannot be found in traditional materials. The main successes have been in special electrical and magnetic properties that have critical applications in a host of electronic devices.

A second use is structural ceramics, designed to solve modern industrial problems such as the construction of aerospace engines, the manufacture of replacement parts for the human body, or the containment of nuclear waste products. They are extraordinarily strong owing to the nature of their structure at atomic level, and they can also withstand heat, wear, corrosion and chemical attack. However, they can also be brittle; one has only to think of a porcelain plate, which does not deform under a load but which can crack and break. Scientists are working to counter this brittleness at atomic level, by trying to fill in the voids between atoms, either with extra oxygen atoms, or by crushing/pressing material during the sintering process in order to achieve a void-free microstructure. Another way to combat brittleness is to utilise composites, which are formed when a ceramic matrix is reinforced with fibres, whiskers or dispersions of other metallic or polymeric materials. A popular composite is that of ceramics reinforced with carbon fibre, materials that are strong

[279] Liu Hsin-Yüan (1993), pp. 41, 83.

and light enough to form the outer skins of space planes and hypersonic aircraft.[280] A well-publicised use for such materials was the employment of carbon-fibre reinforced quartz glass composite and carbon-fibre reinforced carbon composite as protective coating for the space shuttle. However, although it is relatively simple to make polymer composites by surrounding fibres with liquid plastic, it is difficult and expensive to create similar matrices with ceramics and fibres. This is because usual processing techniques of powder compaction and sintering prevent densification and cause cracking.[281] Another new and emerging area of advanced ceramics is connected with advanced and speciality glasses, for example glass optical fibres and electronic glasses. Mixtures of inorganic and organic components on a molecular level (polyceramics) have special optical properties.

A third area in which new materials have advantages over traditional ones lies with first-world concerns about environmental pollution, energy security, the maintenance of economic growth and the formation of capital. It has been proposed that, in addition to meeting needs, materials science and engineering provide society with new ways to address these problems.[282] While it is true that opportunities have been created in the process of research and manufacture of advanced materials, at present benefits are most strongly observed in developed countries, where advanced ceramics play a major part in certain industries: electronics, aerospace and defence, telecommunications, transport, construction, healthcare and nuclear.[283] While new materials can potentially help control pollution and can sustain new industries, the implications of increased consumption of advanced materials are not all beneficial. In environmental terms, effluents produced, for example, in the manufacture of ceramic powders or organic resins are not qualitatively different to those spewed out in traditional mining processes. Although advanced materials substitute for scarce minerals (for example, the replacement of copper wire by optical fibres in communications applications), this in itself could exacerbate critical economic and environmental problems in the third world by superseding requirements for raw materials.[284] The other side of this problem is that wars are fought in Africa for the control and marketing of elements such as tantalum.

Evolution and Competition of Materials

In one way, the evolution of new materials mirrors the lengthy process of development of traditional ceramics, i.e. in the desire to meet customer demand. Thus in

[280] Japan devotes enormous research time to this kind of work, which is undertaken by MITI laboratories and companies in the traditional ceramic area of Nagoya 名古屋.

[281] One simple, cheap alternative proposed uses thin sheets of silicon-carbide powder that are coated with graphite to give weak interfaces between layers; this weakness deflects growing cracks in the composite and promotes toughness. The substance is then pressed and sintered without pressure to give a material of great strength, toughness and heat resistance. See Clegg *et al.* (1990); Cahn (1990), p. 423.

[282] Clark & Flemings (1986), p. 44.

[283] Spriggs (1991), p. 8.

[284] The sale of such materials as oil, copper, nickel, cobalt, chromium and manganese currently supports the economies of countries like Gabon, South Africa, Zaire, Zambia, Zimbabwe, Brazil, Chile, Peru and Papua New Guinea. See Clark & Flemings (1986), pp. 47–9.

China, potters evolved new products empirically to meet buyers' expectations. Once a satisfactory ceramic type had been arrived at, conservative taste ensured that its usage could continue with minor modifications for hundreds of years. However, changes in fashion and taste could be relatively rapid. Thus matt, grey-green glazed ceramics from the Yüeh kilns of northern Chekiang province were overtaken in popularity by higher-fired products from further south in the province during the course of the +11th century. Potters trekked south and were soon involved in the manufacture of Lung-chhüan ceramics whose popularity would remain unchallenged well into the +15th century.

In the +20th century, both development phases and duration of usage of new materials are much more rapid. The main reasons for this are twofold: firstly, as already mentioned, entirely new materials that do not rely on existing raw materials can be created to meet specific requirements; and secondly, because technical progress in materials science has generated an extremely wide range of materials. The resulting superabundance of choice ensures competition between several different materials over which one will be chosen for a certain period of time in a specific application at a given cost. For example, an engineering designer does not automatically select ceramic products; the choice is affected by conditions that a material must withstand, such as corrosion, heat resistance, or cost. Two, three or even four choices of material may be on offer.

Competition of materials is not entirely a recent phenomenon. The starting-point for many technical breakthroughs has been the development of a specific material: glazed stoneware for liquid storage containers; silicon for computer technology; optical fibres for opto-electronics; ceramics for high-temperature engineering, etc. The big change in the +20th to +21st centuries is that in previous ages individual materials had monopoly over certain applications, for example baked earthenware for building bricks; iron for weapons, agricultural tools and cooking pots.

Many of the most interesting developments in ceramic technology take place when techniques are extended or translated into other spheres. In China a technological breakthrough was achieved in transforming the early updraft kiln to a cross-draft kiln, by the simple expedient of turning the kiln design on its side (see Part 3). Such a change was necessitated by requirements for higher firing temperatures and greater capacity. In the case of advanced ceramics, fascinating results will be achieved at the point when everyday tableware can utilise superior achievements of new technology.

In the recent past, Japan has been a world leader in product development, owing to the way that Research and Development and factory outputs are closely linked, enabling rapid transition of ideas from the laboratory to the workplace.[285] In the +21st century, one may hope for world-wide developments that will have discernible effects in the home. Imagine, for example, a cup made of material as white and

[285] See Lastres (1994).

translucent as porcelain with a smooth surface that can accept beautiful decoration; that insulates hot liquids without transferring heat to the hand; that is tough enough to withstand thousands of immersions in the dishwasher without surface impairment; and that can be dropped on a hard surface without danger of cracking or breaking.

An accepted theory is that the early advances in technology in primitive societies are the hardest, and that they take the longest time to achieve. Thus in China it took several thousand years before pots were separated from the fire used to bake them. Even so, the simple updraft kiln and the fast wheel were developed early, during the Neolithic period. During the Bronze Age the pace of technological development increased, to include the production of the world's first ceramics with high-firing glazes. Porcelain was first made *c.* +575 in northern China. In south China, a kiln was developed which was to have far-reaching effects on ceramic developments not only in China, but also in Japan and Korea, over a period of more than 2,000 years. The hill-climbing dragon kiln was efficient for firing large numbers of pieces, using locally available wood and brushwood as fuel.

Looking to the present and to the future, one can envisage China's role in international developments in ceramic technology as being significant. Links with state military and nuclear programmes will ensure that capital research is concentrated in those areas. A burgeoning manufacturing market in a low-wage, educated population means that industries such as electronics will flourish. China's position as one of the booming Pacific Rim nations has been noted by many commentators.

One important facet of +20th- to +21st-century ceramic production that can be noted is an apparent dichotomy between high-technology developments in industry and self-consciously old-fashioned craft manufacture. This situation obtains in all developed countries of the world, where it seems that nostalgic preconceptions about materials and processes can influence art ceramics. In China at least three levels of production can be identified:

- powder pressing and sintering are employed for advanced materials
- techniques such as slip-casting and microwave drying are replacing traditional processes such as throwing at large factories turning out antique replicas and tableware, for example, Ching-te-chen 景德鎮 and Yü-hsien 禹縣
- individual hand-forming and finishing give added value to high-cost ceramics such as I-hsing 宜興 teapots, made for wealthy overseas collectors.

Thus there is no automatic transition from high-technology ceramics, such as those developed in defence-related programmes like Star Wars, to mass technology. It will be necessary first to design and build equipment for processing and forming new materials cheaply, so that they become cost effective in comparison with traditional materials. Then it will need to become the norm for small-scale ceramics producers to utilise new materials alongside accustomed ones, as needs dictate. Finally, it will be encouraging to see individual artists and craftspeople handling high-technology materials with confidence, and utilising their unique qualities to realise innovative art and design ideas.

A Period of 'Reverse Technology Transfer' for China

In the +20th century, China continued to use long-standing and often outmoded processes in the manufacture of traditional ceramics. Certain techniques, such as the achievement of new high-firing underglaze colours, were introduced from Western Europe and Japan. In the development of advanced ceramic technologies also, China was obliged to reach beyond her own national boundaries. We have described the key role played by the Soviet Union in the +1950s. For more than 50 years, however, China was also heavily dependent on Western and Japanese work in the area. Key figures who have helped to power the development of advanced ceramics in China received their training overseas.[286] Thus both in the introduction of new processes, and in the training of specialist personnel, the +20th century could be said to represent a time when reverse technology transfer was operating, i.e. from West to East.

That process slowed after +1977 and today expanding research, development and production is taking place at many top universities and institutes. Within the field of the science and technology of ancient ceramics, for example, the first international meeting was held in +1982 and has continued regularly thereafter.[287] This research area was pioneered by the Shanghai Institute of Ceramics 上海硅酸鹽研究所, an organisation that has played an important role in the development of advanced ceramics in China. The Institute is one of the many research institutes affiliated to CAS. A section on its work is included here as an exemplar of China's work on technical and functional ceramics in the +20th to +21st centuries.[288] Many other academic, industrial and commercial units are undertaking work in the field, but few have sought to pursue research into historical ceramics alongside their major business activity.

At Shanghai, research was originally undertaken by an establishment called the Institute of Metallurgy and Ceramics 治金陶瓷研究所. This was divided into two institutes in +1959, the Institute of Metallurgy 治金研究所 and the Institute of Silicate Chemistry and Technology 硅酸鹽化學與工學研究所. The present title Shanghai Institute of Ceramics was awarded in +1984. As of +1998, the Institute had about 800 staff, half of them being scientific researchers and technicians. It has ten research laboratories, two open laboratories, one analysis and testing centre for inorganic materials, one Research and Development Centre, a high-technology corporation (SICCAS),[289] a pilot plant and a machine shop. The main research field

[286] For example, pioneers at the Shanghai Institute of Ceramics. The Institute's first Director, Chou Jen 周仁, studied at Cornell University in the USA, while Honorary Director Yen Tung-Sheng 嚴東生 studied at the University of Illinois.

[287] The proceedings for the conferences held in +1982, +1985, +1989, +1992, +1995, +1998 and +2002 are detailed in the bibliographies of this volume, and have provided staple materials for its writing.

[288] Information for this section provided by Chang Fu-Khang 張福康.

[289] An acronym for Shanghai Institute of Ceramics, Chinese Academy of Sciences 中國科學院上海陶瓷研究所.

of the Shanghai Institute of Ceramics is inorganic non-metallic materials and materials science. It has produced several notable scientists, among them its first Director, Chou Jen 周仁, whose expertise bridged traditional and technical ceramics; Honorary Director Professor Yen Tung-Sheng 嚴東生 who specialised in high-temperature structural ceramics but has also contributed to many papers on historical ceramics; Chairman of the Academic Council Professor Yin Chih-Wen 殷之文 whose field is functional ceramics; former Director Kuo Ching-Khun 郭景坤 who worked with high-temperature structural ceramics; and Professor Ting Chhuan-Hsien 丁傳賢, well known for his work on ceramic coatings.

Since the mid +20th century the Shanghai Institute of Ceramics has followed its main research impetus by refining many advanced, inorganic, non-metallic compounds. We list below some important research areas:

Synthetic Single Crystals

Scintillation crystal bismuth germanate $Bi_4Ge_3O_{12}$ (BGO) is a material that can produce fluorescent emission under exposure to high-energy particles. Because of this effect, it has found a wide range of applications in high-energy physics, nuclear physics, space physics, nuclear medical instruments, geological prospecting and other high-technology industries.[290] Electro-optic crystal lithium niobate ($LiNbO_3$) has an attractive combination of piezoelectric and electro-optic properties which are very useful in surface acoustic wave devices, electro-optic and non-linear optic devices, etc.

- Piezoelectric crystal lithium tetraborate $Li_2B_4O_7$ (LBO)

Has currently been used for pager, cordless phone and data communication. Some other types of piezoelectric crystals such as quartz, $LiNbO_3$ and $LiTaO_3$ have also been developed.

- Acousto-optic crystals TeO_2 and $PbMoO_4$

Current uses include those of modulator, deflector and tunable filter, etc.

- Non-linear optical crystal barium metaborate BaB_2O_4 (BBO)

Widely applied to various non-linear optical devices.

- Gem stones

Ruby, sapphire, cubic zirconia, star ruby, cat's eye, etc.

- Super-hard materials

For example, synthetic diamond, cubic BN, etc.

[290] Some other types of scintillation crystals including BaF^2, PbF^2 and CeF^3 have also been developed.

High-Temperature Structural Ceramics (High-Temperature Engineering Ceramics)

Materials that are widely used as a substitute for metal in the manufacture of mechanical sealing rings, cutting tools, roller guides, ceramic bearings, scissors, non-magnetic screwdrivers, grinding media, milling balls cylinders, tappets, nozzles, piston crowns, piston seats, precombustion chambers, valve caps and other structural parts in diesel engines, etc. They consist of:

- Alumina ceramics
- Silicon carbide ceramics (SiC)
- Silicon carbide based composite ceramics, such as SiC-whisker reinforced SiC ceramics, etc.
- Silicon nitride ceramics (Si_3N_4)
- Silicon nitride based composite ceramics, including 'Sialon' ceramics and Si_3N_4 ceramics reinforced by carbon fibre, SiC whiskers or BN fibres
- Multiphase composite ceramics
- Y_2O_3 stabilised tetragonal zirconia ceramics (Y-TZP)
- Y-TZP based composite ceramics

Functional Ceramics (Electronic Ceramics)

These ceramics are defined as having superior piezoelectric, ferroelectric, electronic, magnetic, optic, acoustic and thermal properties. They are widely used in various electronic devices for home appliances, industrial and high-technology products. Some functional ceramics developed in China are:

- Piezoelectric ceramics ($PbO\text{-}ZrO_2\text{-}TiO_2$ ceramics or PZT)

Used in ultra-sonic transducers, sensors, igniters, filters, underwater acoustic transducers, etc.

- Ferroelectric ceramics ($PbO\text{-}La_2O_3\text{-}ZrO_2\text{-}TiO_2$ ceramics or PLZT)

Widely employed in transducers, sensors, electrostrictive and photostrictive devices.

- Positive temperature coefficient ceramics (PTC)

Utilised in sensors, temperature compensators, over-heating and over-loading protection, degaussers of colour televisions, motor starters, delaying switches and self-regulating heaters.

- Fast ion conductors

Successfully employed in zirconia oxygen analysers, alumina hydrogen analysers, acidity transmitters, fuel batteries, etc.

Ceramic Coatings

Thermal control coatings give spectral selective absorption or reflection to the thermal emission of the sun, and are used on spacecraft and satellites. Wear-resistance coatings are extremely hard and have low friction coefficients, and are employed in protecting metal components such as sealing rings, rollers and sleeves. Bioceramic coatings have good biological compatibility and thus are useful in manufacturing artificial bones, teeth and joints.

Amorphous Materials

These consist of:

- Amorphous silicon that has good energy conversion efficiency and is used for solar cells
- Optical fibres that are found in optical communication fibre lasers, fibre sensors, laser surgery and other applications
- Glass ceramics that have excellent thermal shock resistance and good wear resistance and are employed in the making of cookware, microwave ovenware, etc.
- Photochromic glasses that are sensitive to sunlight and are needed for protective spectacles.
- Solder glass powder
- Synthetic coloured quartz

In addition to processing technology, the Shanghai Institute of Ceramics has also paid great attention to basic research in materials science. Projects have been devoted to such fields as phase diagrams, the relationship between processing technology and microstructural properties of materials, the mechanism of sintering, recrystallisation, the process and mechanism of strengthening and toughening ceramics, and the 'tailoring' and designing of new ceramic materials with appropriate chemical compositions, specific microstructures and desired properties. In the last half century, the Institute has published numerous papers on the technology and materials science of the topics outlined above. A lot of the materials described were not just laboratory inventions, for they were put into production either by the Research and Development Centre of the Shanghai Institute, or by outside factories after technical transfer of information. Most of the materials created were used in the domestic market. However, a few of them, such as synthetic single crystals BGO and CsI, became highly competitive in the world market because of their superior quality and reasonable price. In recent years, the Research and Development Centre has become an internationally renowned producer and supplier of BGO.

Since the +1990s, the Institute has paid great attention to the development of nano ceramics and nano ceramic composites. These new materials are made from nano(metre)-sized powders and have nano-sized microstructures after firing, so the

ceramics have extremely fine, ultra-pure bodies. Nano materials possess wonderful properties and are believed to be the most promising high-temperature structural materials for development in the +21st century.

We have already mentioned the work done by a small group at the Shanghai Institute of Ceramics, researching the microstructures and processing technologies of ancient Chinese ceramics. Although this has been a minority concern at the Institute itself, its impact and inspiration has been truly international. It was this small core of scientists who, working from the +1950s in a largely unexplored field, developed a methodology and research framework that has inspired the investigations of hundreds of people around the globe. Their initiative has played no small part in the successful completion of this volume of *Science and Civilisation in China.*

SUMMARY OF PART 7, 'TRANSFER'

China is triply blessed in its ceramic traditions. In the first place, its raw materials are unmatched outside the country. Secondly, the technical skills of its potters are outstanding, and thirdly, the richness and complexity of its culture created one of the most sophisticated markets for ceramics in the world. The technical and aesthetic success of this native tradition generated a huge demand for Chinese ceramics beyond the country. This not only exerted a return influence on China through the production of wares in foreign taste, but also had a profound effect on the receiving countries' own ceramic evolutions.

In terms of overall chronology, the influence that China exerted on world ceramic history began some 2,000 years ago in countries adjoining China such as Vietnam and Korea, following their incorporation within the Han empire,[291] and continued to be felt strongly in countries across South-east and East Asia for the next two millennia. Following China's lead, many countries in the region learned to exploit their own refractory clays for the manufacture of unglazed and ash-glazed stonewares, while in Korea and in Japan the occurrence of pure porcelain stone led to the production of quartz-mica porcelain that was comparable in character to that of southern China.

From the +8th through to the +18th centuries, Chinese export wares directly affected the production of fine ceramics in countries as diverse as Mesopotamia, Egypt, Persia, Turkey, Japan, Saxony and Russia.[292] Low-firing white 'stone-paste' ceramics, made first in Egypt and Iran in the +11th to +12th centuries, were often used to imitate Chinese porcelains with local materials.[293] The Old World tin-glaze tradition that began in Mesopotamia in the late +8th century, and then spread northwards through the Near East and across Europe and the New World over the next

[291] Stevenson (1997), p. 27; Barnes (1993), p. 217.
[292] Allen (1991), pp. 6, 34, 50–67; Impey (1996), pp. 26–9; Kingery (1986).
[293] Mason & Tite (1994a), pp. 34–7.

1,000 years was also stimulated by the perceived qualities of Chinese export wares.[294]

In the fine white ceramics of Europe, West Asia and North Africa, which are essentially 'reactive' ceramic traditions (that is with their technologies often based on local interpretations and re-creations of imported Chinese wares), clay recipes tend to be much more artificial constructions. Materials used for the imitation of Chinese wares often contained prepared and crushed glasses ('frits'), while other raw materials might have been brought hundreds or even thousands of miles to the ceramics workshops. An extreme example of this principle occurred in the +18th century when American clays were imported to London to make some early porcelains.[295]

Present-day industrial whiteware technologies of the West derive largely from attempts to copy Chinese porcelains in the +18th century. In addition to that trend, over the last hundred years or so artist potters in Japan, Europe, America and Scandinavia have produced work that embodies a late influence of Chinese ceramic technology on world ceramics.[296]

China's influence in world ceramic history was eclipsed during the +19th and early +20th centuries, but over the last 50 years, China's potters and scientists have sought to build new excellence, not only in the field of traditional ceramics, but also in the ever-expanding area of modern, high-technology ceramics.

[294] Mason & Tite (1994b), p. 34, writing about Abbasid pottery from Iraq, state: 'In the eighth century we see the appearance of crystals of tin oxide in glazes otherwise identical to pre-Islamic opaque alkaline glazes containing a little lead, and by about 800 the full tin-opacified glaze predominantly fluxed by lead was in production.'

[295] Freestone (2000), p. 26.

[296] Leach (1940); Wood (1991), pp. 63–6.

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Thang , +761.
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Ku Khuang 顧 況.

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Northern Sung, +1049–64.
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Ming, *c.* +1595.
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SKCS, TLKKTS.

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CHSC.

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Chhing, +1904.
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Ming, +1612.
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Miscellaneous Notes on Chhüan Nan [Geographical Notes on Fukien Province].
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Chou.
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Drawings and Lists of All Antiques Known at the Hsüan-Ho Reign Period, Revised Edition.
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Begun Chhing, Khang-Hsi reign.
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Great Gazetteer of Chiangsi Province.
Ming, +1556.
Wang Tsung-Mu 王宗沐.
7 chüan.
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Geography and Topography of Chiangsi Province.
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Lin Thing-Kun *et al.* 林庭棍.
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Chhing, +1732, An Shih-Ting *et al.* 安世鼎.
Chhing, +1880–1, Li Wen-Min 李文敏.
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Annals of the Chih-Cheng Reign Period (+1341–68).
Yuan, +1363.
Khung Chhi 孔齊.
YYTTS.

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Chhing, +1765.
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History of the Chin (Jurchen) Dynasty (+1115–1234).
Yuan, *c.* +1345.
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Collection of Texts on Bronze and Stone.
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History of the Chin Dynasty (+265–420).
Thang, +635.
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Gazetteer of Ching-hsing County.
Chhing, +1730.
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MSTS.
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Wu Tai, +945.
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Compilers unknown.
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SSCCS.

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Southern Sung, +1225.
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The Book of Master Chuang.
Chou, *c.* −290.
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SPTK.

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Assisting Notes to the *Erh Ya* Dictionary.
Southern Sung, +1174.
Lo Yüan 羅願.
HYTC.

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Gazetteer of Fu-liang County.
Chhing, +1682.
Revised editions Chhing, +1783, abridged version +1851.
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HMTTS.

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Abridged and Derived from *Thao Cheng* (Pottery Management) in Ch. 4 of *Fu-liang Hsien Chih*.
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HMTTS.

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Random Entries from the Sunny Spot Where One Warms One's Back in Winter.
Southern Sung, *c.* +1200–1279.
Ku Wen-Chien 顧文薦.
SF.

Fu Thien Chi 甫田集.
Collection of Fu Thien.
Ming, *c.* +1530–59.
Wen Cheng-Ming 文徵明.

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Sea Tales.
Ming, +1536.
Huang Ai 黃衷.
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HHSC.

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The Book of Master Han Fei.
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Han Fei 韓非.

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History of the Former Han Dynasty (−206 to +24).
Eastern Han, *c.* +100.
Pan Ku 班固.
Partial trans. Dubs (1938); Swann (1950).
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Remnant Literary Masterpieces of the Han and Wei Dynasty.
Late Ming, +17th century.
Chang Yün-Thai & Yü Yuan-Hsi 張運泰, 餘元熹.
SKCSTMTY.

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History of the Later Han Dynasty (+25–220).
L/Sung, +450.
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Cf. Bielenstein (1954, 1959, 1967, 1979).
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Records of the Collection of Antiques of the Whistling Studio.
Northern Sung, *c.* +1123.
Wang Chhiu 王俅.
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An Exposition of *Khao Kung Chi* from the Studio of Shared Experience.
Southern Sung, *c.* +1250–73.
Lin Hsi-I 林希逸.
CYWYKSKCS.

Hsin Chuan Ching Pan Kung Shih Tiao Cho Cheng Shih Lu Pan Ching Chiang Chia Ching 新鐫京板工師雕斫正式魯班經匠家鏡.
Official Classic of Lu Pan and Artisans 'Mirror for Carpenters and Carvers, Printed from Newly Engraved Blocks from the Capital.
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Earliest extant edition Ming, Wan-Li period (+1573–1619).
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Wu Jung, Chang Yen, Chou Yen 午榮, 章嚴, 周言.
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New History of the Thang Dynasty.
Northern Sung, +1060.
Ou-Yang Hsiu, Sung Chhi *et al.* 歐陽修, 宋祁等.
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Ming, +1436.
Fei Hsin 費信.
SWSC, Shanghai 1936.

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Local Gazetteer of Hsing-hua.
Chhing, +1755.
Liao Hsin-Chhi *et al.* 廖心琦等.

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Illustrated Record of Koryŏ by an Envoy from the Court of Hsüan Ho.
Sung, +1124.
Hsü Ching 徐兢.
SKCSTMTY, Balazs & Hervouet (1978).

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Catalogue of Tripod Vessels of the Hsüan-Te Reign Period.
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SKCS. See Pelliot (1936), Kerr (1990).

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Illustrated Regulations for Ceremonial Paraphernalia of the Chhing Dynasty.
Compiled under imperial orders.
Chhing, +1759, +1766.
Tung Kao *et al.* 董誥等.

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Collected Ming Dynasty Laws and Regulations.
Ming, +1569.
Repr. The Naikaku Bunko Collection (1966).

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Record of Strange Happenings at I-chien.
Southern Sung, +1166.
Hung Mai 洪邁.
HHSC. Balazs & Hervouet (1978).

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The Classic of Changes [Book of Changes].
Chou with Western Han additions.
Compiler unknown.

I Chou Shu [aka *Chi Chung Chou Shu, Chou Shu*] 逸周書 [汲冢周書, 周書]
Lost History of the Chou Dynasty.
First composition late Chou, late –4th to early –3rd century.
Additional material Western Han.
Compilers unknown.

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New Gazetteer of Ching-hsi County in I-hsing.
Chhing, +1882.
Ying Min, Chou Chia-Mei *et al.*, 英敏, 周家楣等.

I Li 儀禮.
Book of Ceremonials and Rituals.
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Compilers unknown.
Yin-Te Index, no. 6. ICS series
Trans. Steele (1917).

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Han and Thang.
Cheng Hsüan 鄭玄 (Later Han).
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Repr. Commercial Press, Shanghai 1934.

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Local Gazetteer of Jao-chou.
Ming, Cheng-Te period (1506–21).
Revised editions Chhing, +1684, +1872.
Ho Hung-Hsün, Shih Ching-Fang *et al.* 賀宏勛, 石景芳等.

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Notes from the Brush of Jung Chai [i.e. Hung Mai].
Sung, +1180–87.
Hung Mai 洪邁.
Balazs & Hervouet (1978).

Khai-Yüan Thien-Pao I Shih 開元天寶遺事.
Popular Tales and Hearsay From the Khai-Yüan and Thien-Pao Reign Periods (+713–756).
Northern Sung, *c.* +975–985.
Wang Jen-Yü 王仁裕.
Repr. Shanghai 1926.

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Desultory Remarks on Furnishing the Abode of the Retired Scholar.
Ming, +1606.
Thu Lung 屠隆.

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Researches on Archaeology with Drawings.
Northern Sung, +1092.
Lü Ta-Lin 呂大臨.
Balazs & Hervouet (1978).

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The Artificers' Record [a section of the *Chou Li* (*q.v.*)].
Spring and Autumn Period to Warring States Period, *c.* –500 to 450.
Compiler unknown.

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Illustrations of the Artificers' Record (of the *Chou Li*) (with a critical archaeological analysis).
Chhing, +1746.
Tai Chen 戴震.
HYLTC, repr. *SWSC* 1955.

Khuei Thien Wai Chheng 窺天外乘.
Annals Written In Retirement.
Ming, +1589.
Wang Shih-Mao 王世懋.

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(Newly Augmented) Essential Criteria of Antiquities.
Ming, +1388, +1459.
Tshao Chao 曹昭, with preface by Cheng Phu 鄭樸.
Trans. David (1971).

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Imperial Encyclopaedia [or: Imperially Commissioned Compendium of Literature and Illustrations, Ancient and Modern].
Chhing, +1726.
Ed. Chhen Meng-Lei 陳夢雷.
Index Giles (1911).
TWSC, Taipei 1976.

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Notes on the Official System of the Ming Dynasty (title a quotation from the Analects).
Ming, +1585.
Wang Shih-Chen 王世禎.
CYSFHC.

Ku Su Chih 姑蘇志.
Interim Gazetteer of Su-chou.
Ming, +1506.
Wang Ao 王鏊.
CYWYKSKCS.

Ku Yao Chhi Khao 古窯器考.
Critique of Ancient Kiln Wares.
Chhing, *c.* +1800.
Liang Thung-Shu 梁同書.

Kuan Tzu 管子.
The Writings of Master Kuan.
Chou and Western Han.
Attr. to Kuan Chung 管仲.
Trans. Rickett (1985).

Kuang Chih I 廣志繹.
An Interpretation of Extensive Records of Remarkable Things.
Ming, +1597.
Wang Shih-Hsing 王士性.

Kuang Ya 廣雅.
Enlargement of the *Erh Ya: Literary Expositor* (dictionary).
San Kuo (Wei), +230.
Chang I 張揖.

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Secret Palace Memorials of the Khang-Hsi Reign Period, Chhing Documents at the National Palace Museum.
Published by the National Palace Museum, Taipei 1976.

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What Should Be Known [to Officials] About the Factories, Workshops and Storehouses of the Ministry of Works.
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Ho Shih-Chin 何士晉.
Repr. Peking 1987.

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Dynastic History of the [Chhing] Palace.
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Repr. Taipei 1970.

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Historical Supplement [of the period +713–824].
Thang, *c.* +824–906.
Li Chao 李肇.
TTTS.

Kuangtung Thung Chih 廣東通志.
Geography and Topography of Kuangtung Province.
Chhing, Yung-Cheng reign (+1723–35).
Hao Yü-Lin 郝玉麟.

Lao Hsüeh An Pi Chi 老學庵筆記.
Notes from the Hall of Learned Old Age.
Southern Sung, *c.* +1195–1200.
Lu Yu 陸游.
SF. Balazs & Hervouet (1978).

Li Chi 禮記.
[= *Hsiao Tai Li Chi*]
Record of Rites [compiled by Tai the Younger] (cf. *Ta Tai Li Chi*).
Ascr. Western Han, *c.* –70/–50, but really Eastern Han, between +80 and +105, though the earliest pieces included may date from the time of the *Analects* (*c.* –465/–450).
Attrib. ed. Tai Sheng 戴聖.
Actual ed. Tshao Pao 曹褒.
Trans. Legge (1885), Wilhelm (1930).
Yin-Te Index, no. 27.

Li Chi Chu Shu 禮記注疏.
The Li Chi with Assembled Commentaries.
Han and Thang.
Cheng Hsüan 鄭玄 (Eastern Han).
Chia Kung-Yen 賈公彥 (Thang).
SSCCS.

Li Tai Chung Ting I Chhi Khuan Chih Fa Thieh 歷代鍾鼎彝器款識法帖
Copies of Inside and Outside Inscriptions on Bells, Cups and Vessels Throughout the History of China.
Southern Sung, *c.* +1144.
Hsüeh Shang-Kung 薛尚功.
Balazs & Hervouet (1978).

Liang Shu 梁書.
History of the Liang Dynasty [+502–556].
Thang, +629.
Yao Chha 姚察 and Yao Ssu-Lien 姚思廉.

Liu Tsung-Yüan Chi 柳宗元集.
Collected Writings of Liu Tsung-Yüan (contains *Tai Jen Chin Tzhu Chhi Chuang* 代人進瓷器狀 'Delegated Official Report on Porcelain Tribute') ch. 39).
Thang, *c.* +800–819.
Liu Tsung-Yüan 柳宗元.
CHSC 1979.

Lun Yu 論語
Conversations and Discourses (of Confucius).
Chou, late –5th or early –4th century.
Compiled by disciples of Confucius.

Lu Pan Ching 魯班經.
See *Hsin Chuan Ching Pan Kung Shih Tiao Cho Cheng Shih Lu Pan Ching Chiang Chia Ching.*

Lü Shih Chhun Chhiu 呂氏春秋.
Master Lü's Spring and Autumn Annals.
[compendium of natural philosphy.]
Chou (Chhin), –239.
Written by the group of scholars gathered by Lü Pu-Wei 呂不韋.
Trans. Willelm (1928).
Chung-Fa Index, no. 2.
SPTK.

Lung-chhüan Hsien Chih 龍泉縣志.
Gazetteer of Lung-chhüan County.
Revised Chhing, +1762.
Second revised edn +1863.
Su Yü-Lung 蘇遇龍.

Mao Shih Chu Shu 毛詩注疏.
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CHSC, SWSC.

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TABLE OF CHINESE PERIODS AND DYNASTIES

舊石器時代 Palaeolithic			prior to *c.* −6,500
新石器時代 Neolithic			*c.* −6,500 to *c.* −1,900
夏 Hsia dynasty (legendary?)			traditional dates *c.* −2000 to *c.* −1520
商 Shang dynasty			*c.* −1520 to −1050
西周 Western Chou dynasty			−1050 to −771
春秋 Chhun Chhiu period			−770 to −475
戰國 Warring States (Chan Kuo) period			−475 to −221
First Unification	秦	CHHIN dynasty	−221 to −207
漢	HAN dynasty	Chhien Han (Western)	−202 to +9
		Hsin interregnum	+9 to +23
		HOU HAN (Eastern)	+25 to +220
	三國	SAN KUO (Three Kingdoms period)	+211 to +265
First Partition	蜀	SHU (HAN)	+211 to +264
	魏	WEI	+200 to +265
	吳	WU	+222 to +280
Second Unification	晉	CHIN dynasty: Western	+265 to +317
		Eastern	+317 to +420
	劉宋	(Liu) SUNG dynasty	+420 to +479
Second Partition		Northern and Southern Dynasties (Nan Pei chhao)	
	齊	CHHI dynasty	+479 to +502
	梁	LIANG dynasty	+502 to +557
	陳	CHHEN dynasty	+557 to +589
	魏	Northern (Thopa) WEI dynasty	+386 to +535
		Western (Thopa) WEI dynasty	+535 to +556
		Eastern (Thopa) WEI dynasty	+534 to +550
	北齊	Northern CHHI dynasty	+550 to +577
	北周	Northern CHOU (Hsienpi) dynasty	+557 to +581
Third Unification	隋	SUI dynasty	+581 to +618
	唐	THANG dynasty	+618 to +906
Third Partition	五代	WU TAI (Five Dynasty period) (Later Liang, Later Thang (Turkic), Later Chin (Turkic), Later Han (Turkic), and Later Chou)	+907 to +960
	遼	LIAO (Chhitan Tartar) dynasty	+907 to +1124
		West LIAO dynasty (Qarā-Khiṭāi)	+1124 to +1211
	西夏	Hsi Hsia (Tangut Tibetan) state	+986 to +1227
Fourth Unification	宋	Northern SUNG dynasty	+960 to +1226
		建隆 Chien-Lung	+960 to +963
		乾德 Chhien-Te	+963 to +968
		開寶 Khai-Pao	+968 to +976
		太平興國 Thai-Phing Hsing-Kuo	+976 to +984
		雍熙 Yung-Hsi	+984 to +987
		端拱 Tuan-Kung	+988 to +989
		淳化 Chhun-Hua	+990 to +994
		至道 Chih-Tao	+995 to +997

	咸平 Hsien-Phing	+998 to +1003
	景德 Ching-Te	+1004 to +1008
	大中祥符 Ta-Chung Hsiang-Fu	+1008 to +1016
	天禧 Thien-Hsi	+1017 to +1021
	乾興 Chhien-Hsing	+1022 to +1023
	天聖 Thien-Sheng	+1023 to +1032
	明道 Ming-Tao	+1032 to +1033
	景祐 Jing-Yu	+1034 to +1038
	寶元 Pao-Yüan	+1038 to +1040
	康定 Khang-Ting	+1040 to +1041
	慶歷 Chhing-Li	+1041 to +1048
	皇祐 Huang-Yu	+1049 to +1054
	至和 Chih-Ho	+1054 to +1056
	嘉祐 Chia-Yu	+1056 to +1063
	治平 Chih-Phing	+1064 to +1067
	熙寧 Hsi-Ning	+1068 to +1077
	元豐 Yüan-Feng	+1078 to +1085
	元祐 Yüan-Yu	+1086 to +1094
	紹聖 Shao-Sheng	+1094 to +1098
	元符 Yüan-Fu	+1098 to +1100
	建中靖國 Chien-Chung Ching-Kuo	+1101
	崇寧 Chhung-Ning	+1102 to +1106
	大觀 Ta-Kuan	+1107 to +1110
	政和 Cheng-Ho	+1111 to +1118
	重和 Chhung-Ho	+1118 to +1119
	宣和 Hsüan-Ho	+1119 to +1125
	靖康 Ching-Khang	+1126 to +1127
宋	Southern SUNG dynasty	+1127 to +1279
	建炎 Chien-Yen	+1127 to +1130
	紹興 Shao-Hsing	+1131 to +1162
	隆興 Lung-Hsing	+1163 to +1164
	乾道 Chhien-Tao	+1165 to +1173
	淳熙 Chhun-Hsi	+1174 to +1189
	紹熙 Shao-Hsi	+1190 to +1194
	慶元 Chhing-Yüan	+1195 to +1200
	嘉泰 Chia-Thai	+1201 to +1204
	開禧 Khai-Hsi	+1205 to +1207
	嘉定 Chia-Ting	+1208 to +1224
	寶慶 Pao-Chhing	+1225 to +1227
	紹定 Shao-Ting	+1228 to +1233
	端平 Tuan-Phing	+1234 to +1236
	嘉熙 Chia-Hsi	+1237 to +1240
	淳祐 Chhun-Yu	+1241 to +1252
	寶祐 Pao-Yu	+1253 to +1258
	開慶 Khai-Chhing	+1259

	景定 Ching-Ting	+1260 to +1264
	咸淳 Hsien-Chhun	+1265 to +1274
	德祐 Te-Yu	+1275 to +1276
	景炎 Ching-Yen	+1276 to +1278
	祥興 Hsiang-Hsing	+1278 to +1279
金	CHIN (Jurchen Tartar) dynasty	+1115 to +1234
元	YUAN (Mongol) dynasty	+1260 to +1368
	至元 Chih-Yüan	+1264 to +1294 (on Chinese throne from +1280)
	元貞 Yüan-Chen	+1295 to +1297
	大德 Ta-Te	+1297 to +1307
	至大 Chih-Ta	+1308 to +1311
	皇慶 Huang-Chhing	+1312 to +1313
	延祐 Yen-Yu	+1314 to +1320
	至治 Chih-Chih	+1321 to +1323
	泰定 Thai-Ting	+1324 to +1328
	致和 Chih-Ho	+1328
	天順 Thien-Shun	+1328
	天曆 Thien-Li	+1328 to +1330
	至順 Chih-Shun	+1330 to +1333
	元統 Yüan-Thung	+1333 to +1335
	至元 Chih-Yüan	+1335 to +1340
	至正 Chih-Cheng	+1341 to +1368
明	MING dynasty	+1368 to +1644
	洪武 Hung-Wu	+1368 to +1398
	建文 Chien-Wen	+1399 to +1402
	永樂 Yung-Le	+1403 to +1424
	洪熙 Hung-Hsi	+1425
	宣德 Hsüan-Te	+1426 to +1435
	正統 Cheng-Thung	+1436 to +1449
	景泰 Ching-Thai	+1450 to +1456
	天順 Thien-Shun	+1457 to +1464
	成化 Chheng-Hua	+1465 to +1487
	弘治 Hung-Chih	+1488 to +1505
	正德 Cheng-Te	+1506 to +1521
	架靖 Chia-Ching	+1522 to +1566
	隆慶 Lung-Chhing	+1567 to +1572
	萬歷 Wan-Li	+1573 to +1620
	泰昌 Thai-Chhang	+1620
	天啓 Thien-Chhi	+1621 to +1627
	崇禎 Chhung-Chen	+1628 to +1644
清	CHHING (Manchu) dynasty	+1644 to +1911
	順治 Shun-Chih	+1644 to +1661
	康熙 Khang-Hsi	+1662 to +1722

雍正	Yung-Cheng	+1723 to +1735
乾隆	Chhien-Lung	+1736 to +1795
嘉慶	Chia-Chhing	+1796 to +1820
道光	Tao-Kuang	+1821 to +1850
咸豐	Hsien-Feng	+1851 to +1861
同治	Thung-Chih	+1862 to +1874
光緒	Kuang-Hsü	+1875 to +1908
宣統	Hsüan-Thung	+1909 to +1911
民國	Republic	+1912
人民共和國	People's Republic	+1949

ROMANISATION CONVERSION TABLES

By Robin Brilliant

PINYIN/MODIFIED WADE-GILES

Pinyin	Modified Wade-Giles	Pinyin	Modified Wade-Giles
a	a	chu	chhu
ai	ai	chuai	chhuai
an	an	chuan	chhuan
ang	ang	chuang	chhuang
ao	ao	chui	chhui
ba	pa	chun	chhun
bai	pai	chuo	chho
ban	pan	ci	tzhu
bang	pang	cong	tshung
bao	pao	cou	tshou
bei	pei	cu	tshu
ben	pen	cuan	tshuan
beng	peng	cui	tshui
bi	pi	cun	tshun
bian	pien	cuo	tsho
biao	piao	da	ta
bie	pieh	dai	tai
bin	pin	dan	tan
bing	ping	dang	tang
bo	po	dao	tao
bu	pu	de	te
ca	tsha	deng	teng
cai	tshai	di	ti
can	tshan	dian	tien
cang	tshang	diao	tiao
cao	tsho	die	dieh
ce	tshe	ding	ting
cen	tshen	diu	tiu
ceng	tsheng	dong	tung
cha	chha	dou	tou
chai	chhai	du	tu
chan	chhan	duan	tuan
chang	chhang	dui	tui
chao	chhao	dun	tun
che	chhe	duo	to
chen	chhen	e	o
cheng	chheng	en	en
chi	chhih	eng	eng
chong	chhung	er	erh
chou	chhou	fa	fa

Pinyin	Modified Wade-Giles	Pinyin	Modified Wade-Giles
fan	fan	jin	chin
fang	fang	jing	ching
fei	fei	jiong	chiung
fen	fen	jiu	chiu
feng	feng	ju	chü
fo	fo	juan	chüan
fou	fou	jue	chüeh
fu	fu	jun	chün
gai	kai	ka	kha
gan	kan	kai	khai
gang	kang	kan	khan
gao	kao	kang	khang
ge	ko	kao	khao
gei	kei	ke	kho
gen	ken	kei	khei
geng	keng	ken	khen
gong	kung	keng	kheng
gou	kou	kong	khung
gu	ku	kou	khou
gua	kua	ku	khu
guai	kuai	kua	khua
guan	kuan	kuai	khuai
guang	kuang	kuan	khuan
gui	kuei	kuang	khuang
gun	kun	kui	khuei
ha	ha	kun	khun
hai	hai	kuo	khuo
han	han	la	la
hang	hang	lai	lai
hao	hao	lan	lan
he	ho	lang	lang
hei	hei	lao	lao
hen	hen	le	le
heng	heng	lei	lei
hong	hung	leng	leng
hou	hou	li	li
hu	hu	lia	lia
hua	hua	lian	lien
huai	huai	liang	liang
huan	huan	liao	liao
huang	huang	lie	lieh
hui	hui	lin	lin
hun	hun	ling	ling
huo	huo	liu	liu
ji	chi	long	lung
jia	chia	lou	lou
jian	chien	lu	lu
jiang	chiang	lü	lü
jiao	chiao	luan	luan
jie	chieh	lüe	lüeh

Pinyin	Modified Wade-Giles	Pinyin	Modified Wade-Giles
lun	lun	pen	phen
luo	lo	peng	pheng
ma	ma	pi	phi
mai	mai	pian	phien
man	man	piao	phiao
mang	mang	pie	phieh
mao	mao	pin	phin
mei	mei	ping	phing
men	men	po	pho
meng	meng	pou	phou
mi	mi	pu	phu
mian	mien	qi	chhi
miao	miao	qia	chhia
mie	mieh	qian	chhien
min	min	qiang	chhiang
ming	ming	qiao	chhiao
miu	miu	qie	chhieh
mo	mo	qin	chhin
mou	mou	qing	chhing
mu	mu	qiong	chhiung
na	na	qiu	chhiu
nai	nai	qu	chhü
nan	nan	quan	chhüan
nang	nang	que	chhüeh
nao	nao	qun	chhün
nei	nei	ran	jan
nen	nen	rang	jang
neng	neng	rao	jao
ni	ni	re	je
nian	nien	ren	jen
niang	niang	reng	jeng
niao	niao	ri	jih
nie	nieh	rong	jung
nin	nin	rou	jou
ning	ning	ru	ju
niu	niu	rua	jua
nong	nung	ruan	juan
nou	nou	rui	jui
nu	nu	run	jun
nü	nü	ruo	jo
nuan	nuan	sa	sa
nüe	nüeh	sai	sai
nuo	no	san	san
ou	ou	sang	sang
pa	pha	sao	sao
pai	phai	se	se
pan	phan	sen	sen
pang	phang	seng	seng
pao	phao	sha	sha
pei	phei	shai	shai

Pinyin	Modified Wade-Giles	Pinyin	Modified Wade-Giles
shan	shan	weng	weng
shang	shang	wo	wo
shao	shao	wu	wu
she	she	xi	hsi
shei	shei	xia	hsia
shen	shen	xian	hsien
sheng	sheng	xiang	hsiang
shi	shih	xiao	hsiao
shou	shou	xie	hsieh
shu	shu	xin	hsin
shua	shua	xing	hsing
shuai	shuai	xiong	hsiung
shuan	shuan	xiu	hsiu
shuang	shuang	xu	hsü
shui	shui	xuan	hsüan
shun	shun	xue	hsüeh
shuo	shuo	xun	hsün
si	ssu	ya	ya
song	sung	yan	yen
sou	sou	yang	yang
su	su	yao	yao
suan	suan	ye	yeh
sui	sui	yi	i
sun	sun	yin	yin
suo	so	ying	ying
ta	tha	yong	yung
tai	thai	you	yu
tan	than	yu	yü
tang	thang	yuan	yüan
tao	thao	yue	yüeh
te	the	yun	yün
teng	theng	za	tsa
ti	thi	zai	tsai
tian	thien	zan	tsan
tiao	thiao	zang	tsang
tie	thieh	zao	tsao
ting	thing	ze	tse
tong	thung	zei	tsei
tou	thou	zen	tsen
tu	thu	zeng	tseng
tuan	thuan	zha	cha
tui	thui	zhai	chai
tun	thun	zhan	chan
tuo	tho	zhang	chang
wa	wa	zhao	chao
wai	wai	zhe	che
wan	wan	zhei	chei
wang	wang	zhen	chen
wei	wei	zheng	cheng
wen	wen	zhi	chih

Pinyin	Modified Wade-Giles	Pinyin	Modified Wade-Giles
zhong	chung	zhuo	cho
zhou	chou	zi	tzu
zhu	chu	zong	tsung
zhua	chua	zou	tsou
zhuai	chuai	zu	tsu
zhuan	chuan	zuan	tsuan
zhuang	chuang	zui	tsui
zhui	chui	zun	tsun
zhun	chun	zuo	tso

MODIFIED WADE-GILES/PINYIN

Modified Wade-Giles	Pinyin	Modified Wade-Giles	Pinyin
a	a	chhing	qing
ai	ai	chhiu	qiu
an	an	chhiung	qiong
ang	ang	chho	chuo
ao	ao	chhou	chou
cha	zha	chhu	chu
chai	zhai	chhuai	chuai
chan	zhan	chhuan	chuan
chang	zhang	chhuang	chuang
chao	zhao	chhui	chui
che	zhe	chhun	chun
chei	zhei	chhung	chong
chen	zhen	chhü	qu
cheng	zheng	chhüan	quan
chha	cha	chhüeh	que
chhai	chai	chhün	qun
chhan	chan	chi	ji
chhang	chang	chia	jia
chhao	chao	chiang	jiang
chhe	che	chiao	jiao
chhen	chen	chieh	jie
chheng	cheng	chien	jian
chhi	qi	chih	zhi
chhia	qia	chin	jin
chhiang	qiang	ching	jing
chhiao	qiao	chiu	jiu
chhieh	qie	chiung	jiong
chhien	qian	cho	zhuo
chhih	chi	chou	zhou
chhin	qin	chu	zhu

Modified Wade-Giles	Pinyin	Modified Wade-Giles	Pinyin
chua	zhua	huang	huang
chuai	zhuai	hui	hui
chuan	zhuan	hun	hun
chuang	zhuang	hung	hong
chui	zhui	huo	huo
chun	zhun	i	yi
chung	zhong	jan	ran
chü	ju	jang	rang
chüan	juan	jao	rao
chüeh	jue	je	re
chün	jun	jen	ren
en	en	jeng	reng
eng	eng	jih	ri
erh	er	jo	ruo
fa	fa	jou	rou
fan	fan	ju	ru
fang	fang	jua	rua
fei	fei	juan	ruan
fen	fen	jui	rui
feng	feng	jun	run
fo	fo	jung	rong
fou	fou	kai	gai
fu	fu	kan	gan
ha	ha	kang	gang
hai	hai	kao	gao
han	han	kei	gei
hang	hang	ken	gen
hao	hao	keng	geng
hen	hen	kha	ka
heng	heng	khai	kai
ho	he	khan	kan
hou	hou	khang	kang
hsi	xi	khao	kao
hsia	xia	khei	kei
hsiang	xiang	khen	ken
hsiao	xiao	kheng	keng
hsieh	xie	kho	ke
hsien	xian	khou	kou
hsin	xin	khu	ku
hsing	xing	khua	kua
hsiu	xiu	khuai	kuai
hsiung	xiong	khuan	kuan
hsü	xu	khuang	kuang
hsüan	xuan	khuei	kui
hsüeh	xue	khun	kun
hsün	xun	khung	kong
hu	hu	khuo	kuo
hua	hua	ko	ge
huai	huai	kou	gou
huan	huan	ku	gu

Modified Wade-Giles	Pinyin	Modified Wade-Giles	Pinyin
kua	gua	mu	mu
kuai	guai	na	na
kuan	guan	nai	nai
kuang	guang	nan	nan
kuei	gui	nang	nang
kun	gun	nao	nao
kung	gong	nei	nei
kuo	guo	nen	nen
la	la	neng	neng
lai	lai	ni	ni
lan	lan	niang	niang
lang	lang	niao	niao
lao	lao	nieh	nie
le	le	nien	nian
lei	lei	nin	nin
leng	leng	ning	ning
li	li	niu	niu
lia	lia	no	nuo
liang	liang	nou	nou
liao	liao	nu	nu
lieh	lie	nuan	nuan
lien	lian	nung	nong
lin	lin	nü	nü
ling	ling	nüeh	nüe
liu	liu	o	e
lo	luo	ong	weng
lou	lou	ou	ou
lu	lu	pa	ba
luan	luan	pai	bai
lun	lun	pan	ban
lung	long	pang	bang
lü	lü	pao	bao
lüch	lüe	pei	bei
ma	ma	pen	ben
mai	mai	peng	beng
man	man	pha	pa
mang	mang	phai	pai
mao	mao	phan	pan
mei	mei	phang	pang
men	men	phao	pao
meng	meng	phei	pei
mi	mi	phen	pen
miao	miao	pheng	peng
mieh	mie	phi	pi
mien	mian	phiao	piao
min	min	phieh	pie
ming	ming	phien	pian
miu	miu	phin	pin
mo	mo	phing	ping
mou	mou	pho	po

Modified Wade-Giles	Pinyin	Modified Wade-Giles	Pinyin
phou	pou	te	de
phu	pu	teng	deng
pi	bi	tha	ta
piao	biao	thai	tai
pieh	bie	than	tan
pien	bian	thang	tang
pin	bin	thao	tao
ping	bing	the	te
po	bo	theng	teng
pu	bu	thi	ti
sa	sa	thiao	tiao
sai	sai	thieh	tie
san	san	thein	tian
sang	sang	thing	ting
sao	sao	tho	tuo
se	se	thou	tou
sen	sen	thu	tu
seng	seng	thuan	tuan
sha	sha	thui	tui
shai	shai	thun	tun
shan	shan	thung	tong
shang	shang	ti	di
shao	shao	tiao	diao
she	she	tieh	die
shei	shei	tien	dian
shen	shen	ting	ding
sheng	sheng	tiu	diu
shih	shi	to	duo
shou	shou	tou	dou
shu	shu	tsa	za
shua	shua	tsai	zai
shuai	shuai	tsan	zan
shuan	shuan	tsang	zang
shuang	shuang	tsao	zao
shui	shui	tse	ze
shun	shun	tsei	zei
shuo	shuo	tsen	zen
so	suo	tseng	zeng
sou	sou	tsha	ca
ssu	si	tshai	cai
su	su	tshan	can
suan	suan	tshang	cang
sui	sui	tshao	cao
sun	sun	tshe	ce
sung	song	tshen	cen
ta	da	tsheng	ceng
tai	dai	tsho	cuo
tan	dan	tshou	cou
tang	dang	tshu	cu
tao	dao	tshuan	cuan

Modified Wade-Giles	Pinyin	Modified Wade-Giles	Pinyin
tshui	cui	wan	wan
tshun	cun	wang	wang
tshung	cong	wei	wei
tso	zuo	wen	wen
tsou	zou	wo	wo
tsu	zu	wu	wu
tsuan	zuan	ya	ya
tsui	zui	yang	yang
tsun	zun	yao	yao
tsung	zong	yeh	ye
tu	du	yen	yan
tuan	duan	yin	yin
tui	dui	ying	ying
tun	dun	yu	you
tung	dong	yung	yong
tzhu	ci	yü	yu
tzu	zi	yüan	yuan
wa	wa	yüeh	yue
wai	wai	yün	yun